

Monitoring the land surface from MODIS: from science to applications

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with contributions from

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Louis Giglio and Luigi Boschetti

UMD

and

Matt Hansen and David Roy, SDSU

MODIS Land Products

- Initial ATBD process (peer reviewed)
- Explicit funded QA and Validation activities
- 5 major re-processings – C6 in process
- Science products now mature
- Process of Research to Operations underway
- Applications developed
- Large uptake by the international community
- Coarse resolution sensor instrument of choice due to
 - Science Quality – Validation
 - Ease of Access and FREE
 - Extent of Documentation

MODIS Land Products

- **Energy Balance Product Suite**

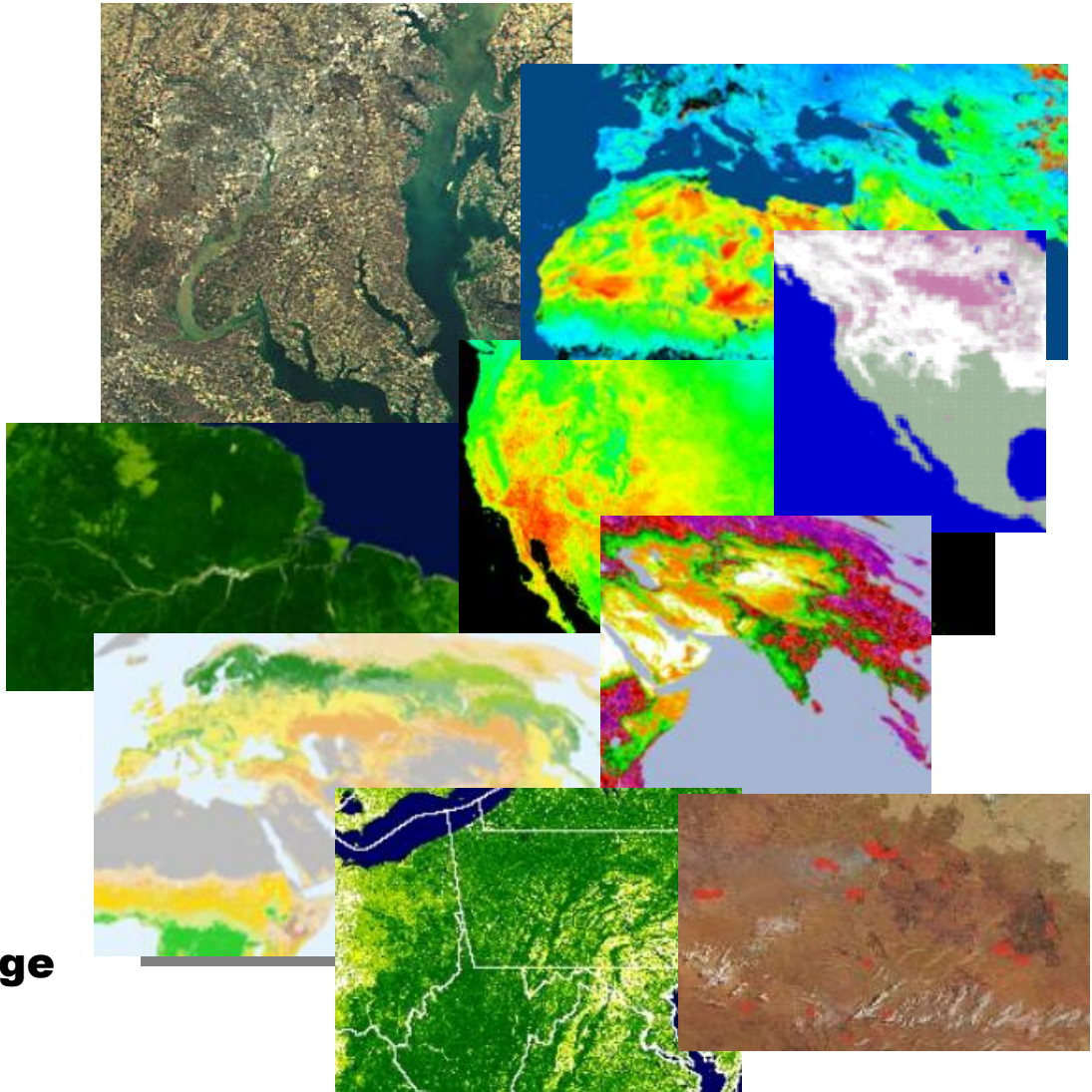
- Surface Reflectance
- Land Surface Temperature, Emmissivity
- BRDF/Albedo
- Snow/Sea-ice Cover

- **Vegetation Parameters Suite**

- Vegetation Indices
- LAI/FPAR
- PSN/NPP

- **Land Cover/Land Use Suite**

- Land Cover/Vegetation Dynamics
- Vegetation Continuous Fields
- Vegetation Cover Change
- Fire and Burned Area

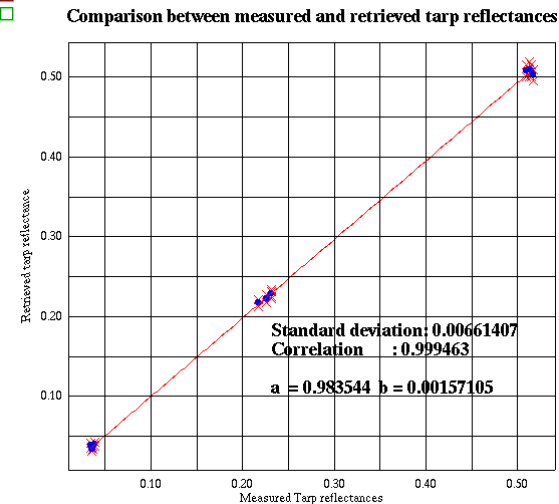
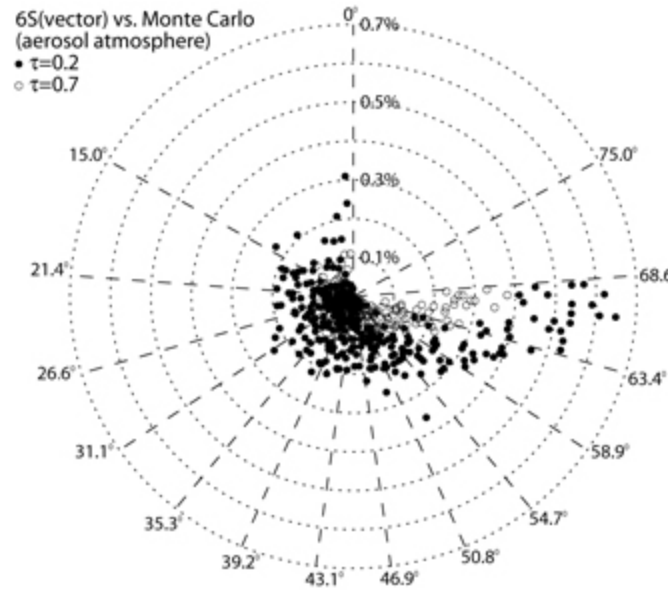
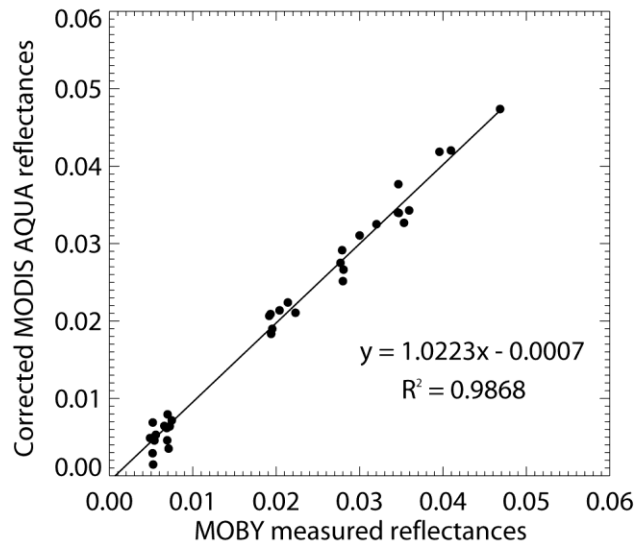



Approach for the surface reflectance product

- Atmospheric correction approach consistent across different sensors , ensuring consistent reflectance data across resolutions and based on rigorous radiative transfer

<http://6s.ltdri.org>

<http://rtcodes.ltdri.org/>



A satellite image showing a large area of Southern Africa and the surrounding Indian Ocean. The land is mostly brown and tan, indicating arid or semi-arid conditions. There are some green patches, possibly vegetation. The ocean is dark blue. The image is a MODIS granule, meaning it covers a large area of the Earth's surface.

MODIS Granule over Southern Africa (Sept 13, 2001, 8:45 to 8:50 GMT)

Red, Green, Blue MODIS top of
atmosphere reflectance

No aerosol correction

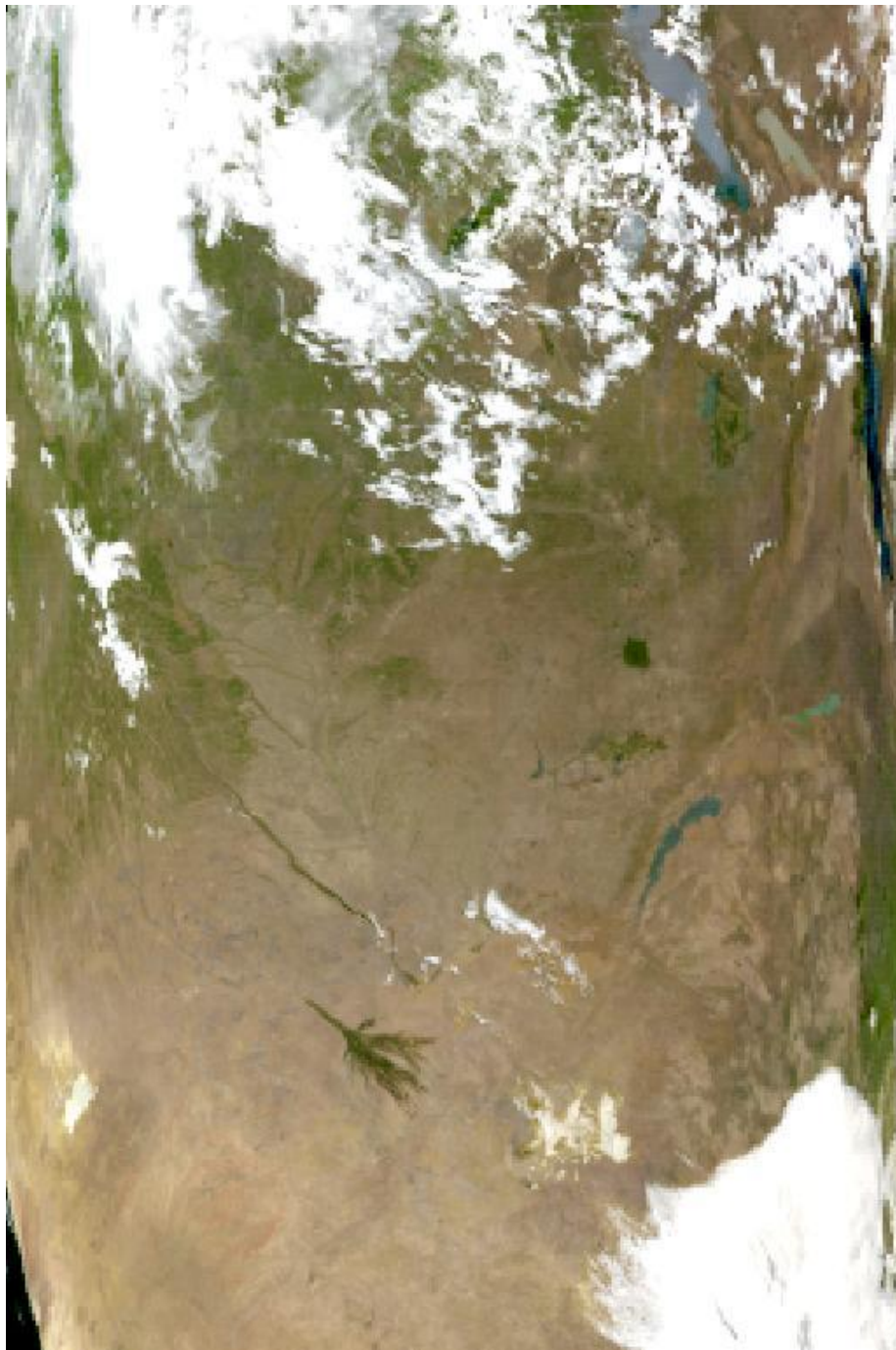
**Surface Reflectance: Atmospheric
effect has a strong impact on
remotely sensed data**

(E. Vermote)

MODIS Granule over Southern Africa
(Sept 13, 2001, 8:45 to 8:50 GMT)

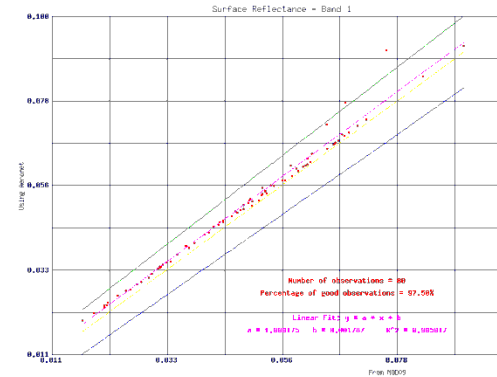
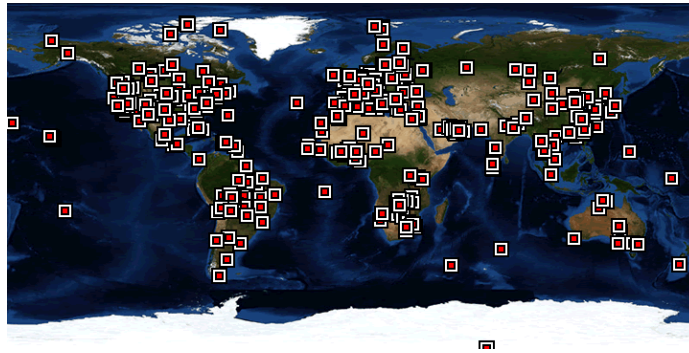
Red, Green, Blue MODIS surface
reflectance

With aerosol correction



(302/000 741 001)

Verification over AERONET sites



Subsets of Level 1B
data processed using
the standard surface
reflectance algorithm

comparison

Reference data set

Atmospherically
corrected TOA
reflectances derived
from Level 1B subsets

Vector 6S

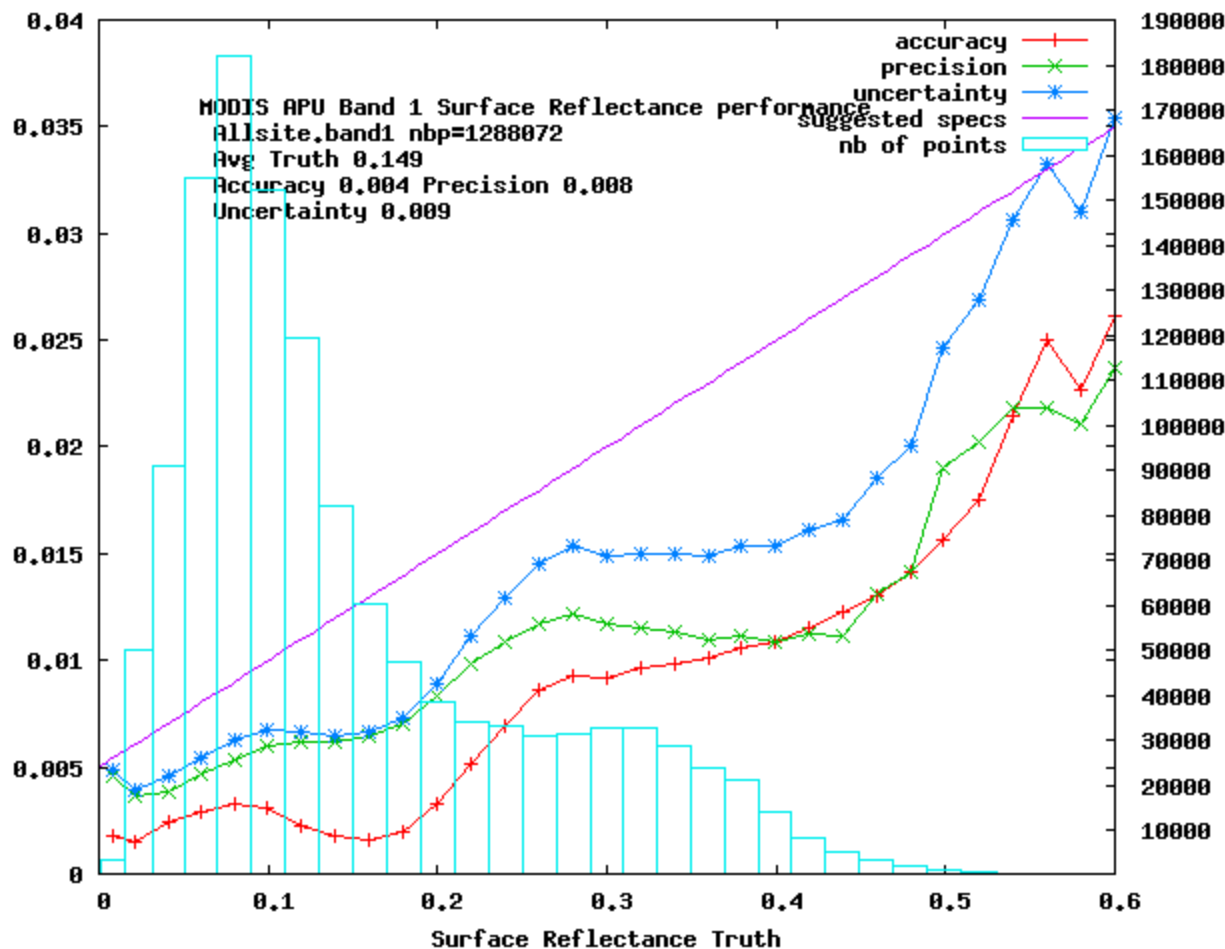
AERONET measurements
(τ_{aer} , H_2O , particle distribution)

If the difference is within
 $\pm(0.005+0.05\rho)$, the observation
is “good”.

http://mod09val.ltdri.org/cgi-bin/mod09_c005_public_allsites_onecollection.cgi

Toward a quantitative assessment of performances (APU)

1,3 Millions 1 km pixels were analyzed for each band.

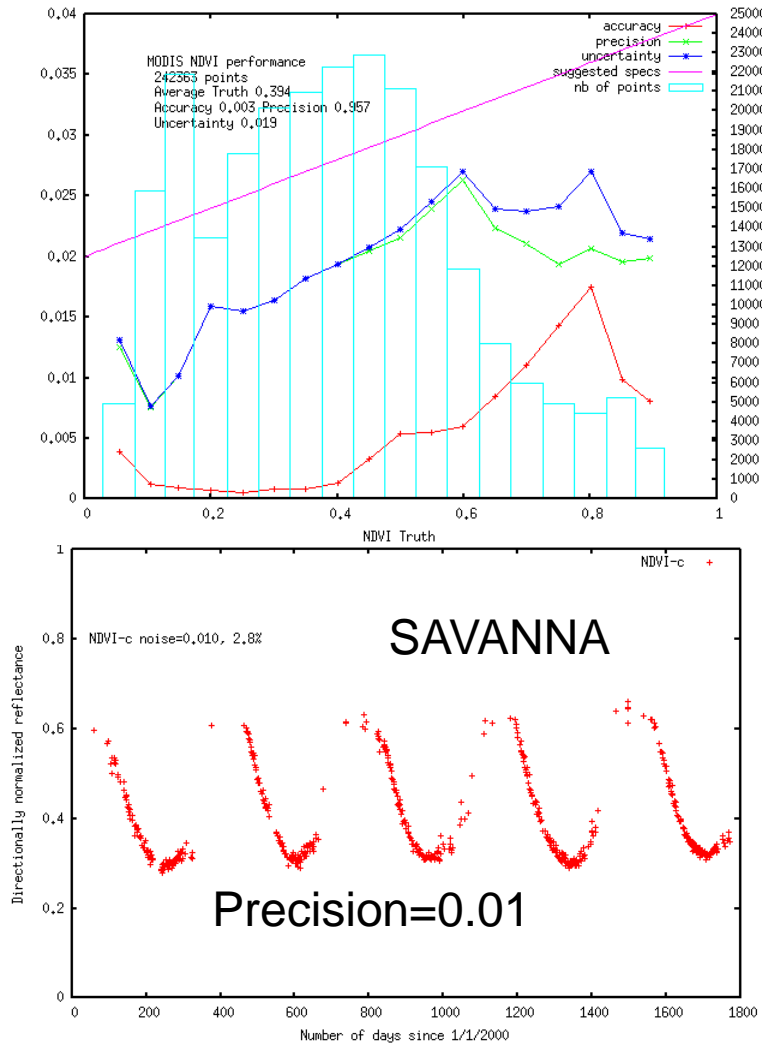


Red = Accuracy (mean bias)
Green = Precision (repeatability)
Blue = Uncertainty (square sum of A and P)

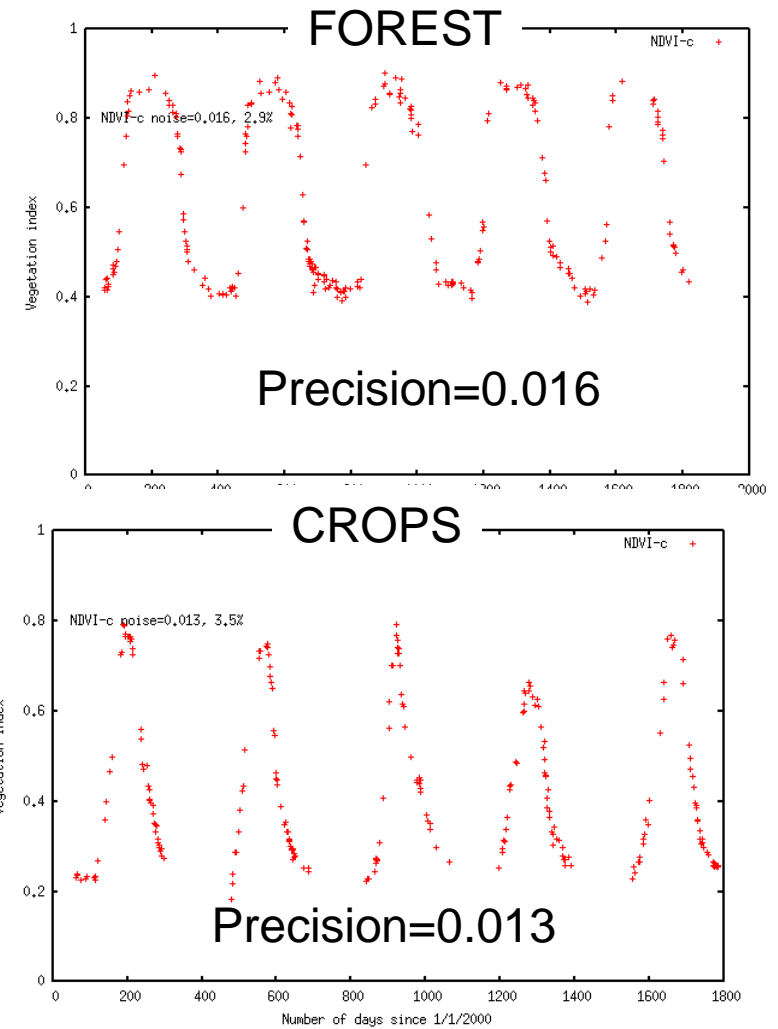
On average well below magenta theoretical error bar

The precision could be verified independently on time series analysis

Evaluation over AERONET (2003)
 $0.007 < \text{Precision} < 0.017$



Independent evaluation of the precision
 Over 2000-2004 CMG daily time series



Utilizing the MODIS Vegetation Index Data



USDA Foreign Agricultural Service

United States Department of Agriculture
Foreign Agricultural Service

Linking U.S. Agriculture to the World

Crop Explorer

Global Food Supply Monitoring

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North America
United States
Canada

Central America
Mexico
Central America and Caribbean

South America
Brazil
Northern South America
Southern South America

Europe
Europe

Middle East
Iran, Iraq, Syria and Turkey

Oceania
Australia

Former Soviet Union
Kazakhstan
Russia, Azerbaijan, Armenia and Georgia
Ukraine, Moldova, and Belarus

Africa
North Africa
Southern Africa
East Africa
West Africa

Asia
Eastern China
South Asia
Southeast Asia
Central Asia
Korea

Site Index

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- [Iraq Operational Agricultural Monitoring Project](#)
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- [Speaker Presentations on Global Food Security Challenges](#)

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- [Global Reser](#)
- [Landsat GloV](#)

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Explore by Crop

a Commodity

commodity Intel

Reports

MODIS NDVI

Region: Australia, East
Date Range: 2006-Sep-14 to 2007-05-24
Shape: Australia Wheatbelt: New South Wales
Detail Point: 28.5303 151.4803
(MODIS)
1 (06/07/07)

Detail Shape 2005-7
Detail Shape 2005-4
Detail Shape Long-term Mean

Urban/
Bare Soil
No Data/
Clouds

Sparse
Vegetation
Dense

Worse than
Normal
Normal
Better than
Normal

MODIS NDVI Histogram

NDVI Value

Detail Box 2005 May-24
Detail Box 2005 May-24
Detail Box 2004 May-23
Detail Box Mean 2005 May-24

GIEWS- Global Information and Early Warning System (UN-FAO)

- Provides global information on food supply and demand
- Provides early warnings of impending food crises in individual countries



Global Information and Early Warning System
- on food and agriculture [GIEWS]

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
helping to build a world without hunger

GIEWS Publications

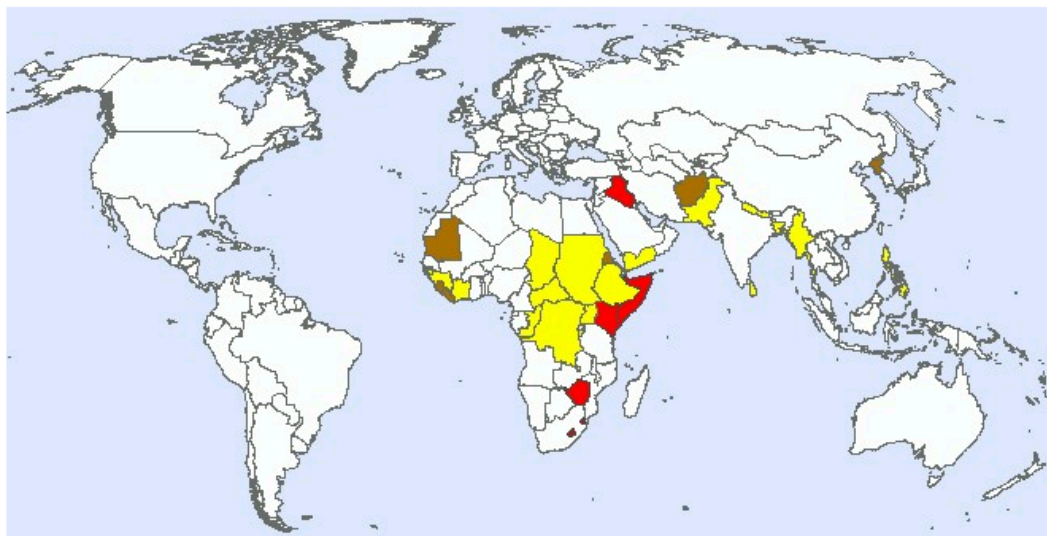


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November 2009

COUNTRIES IN CRISIS REQUIRING EXTERNAL ASSISTANCE (total: 31 countries)

Table View



■ Shortfall in aggregate food production/supplies

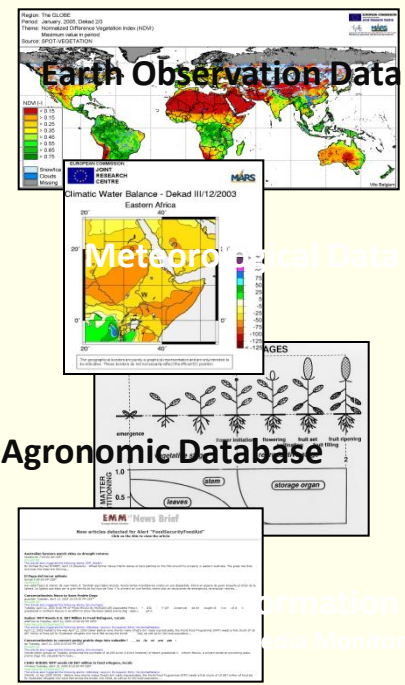
■ Widespread lack of access

■ Severe localized food insecurity

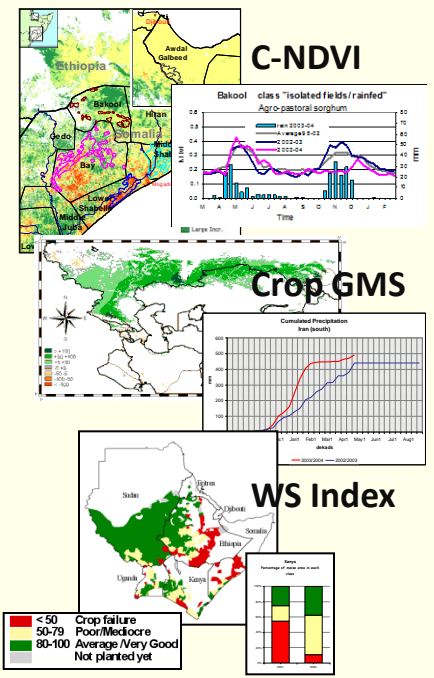
MARS-FOOD Crop Monitoring System

European Commission Joint Research Center (JRC)

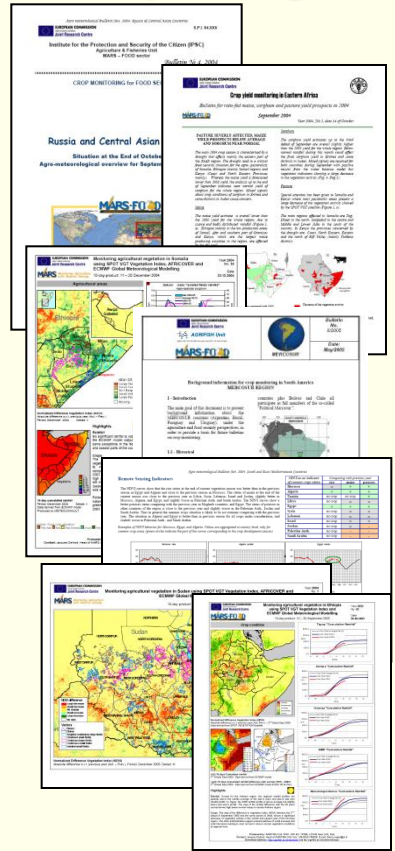
Data collection & retrieval



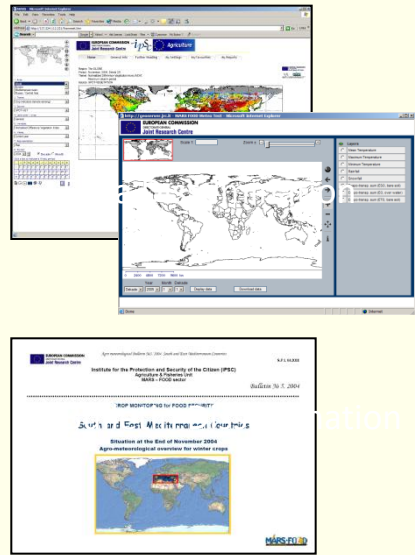
Processing & Analysis



Reporting



Dissemination

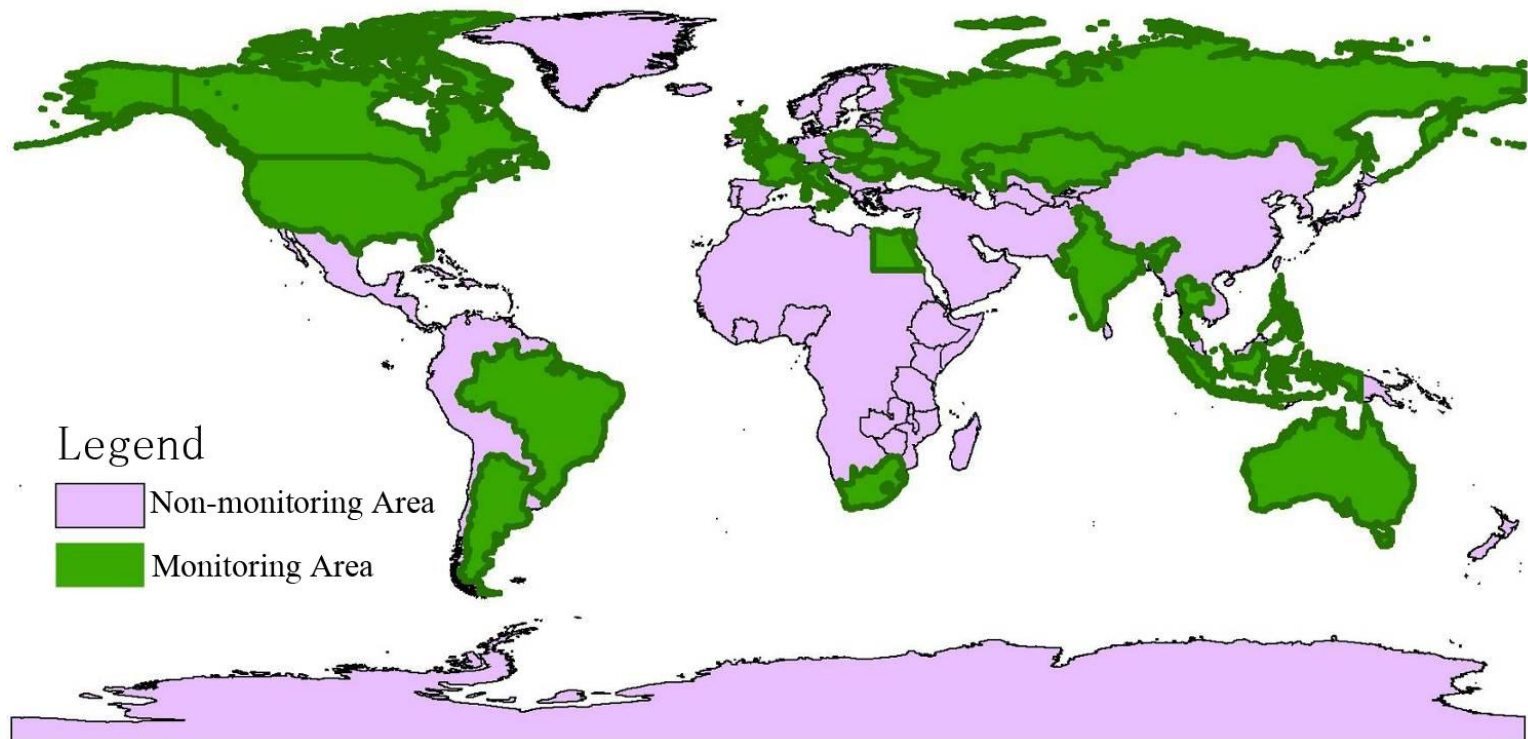


Crop Assessment Process

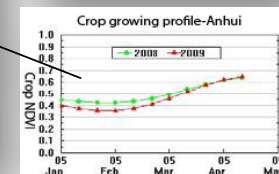
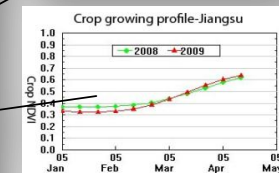
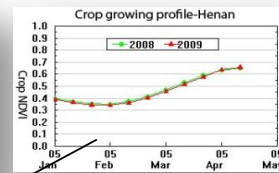
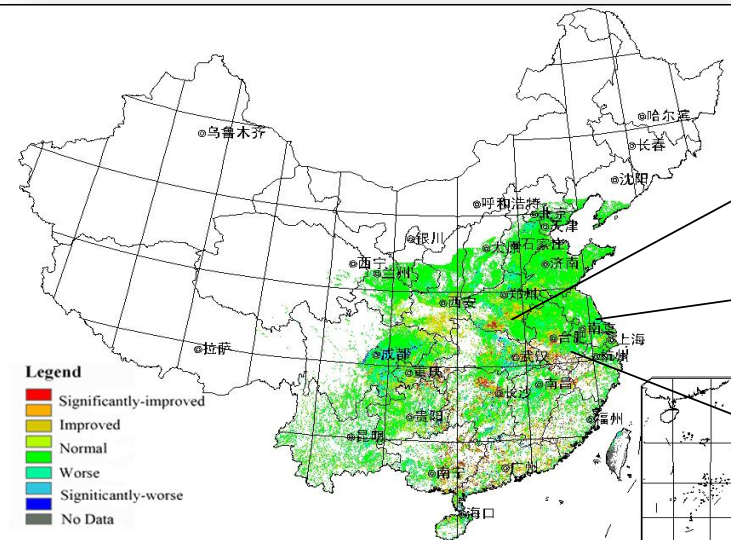


China Global Crop Monitoring

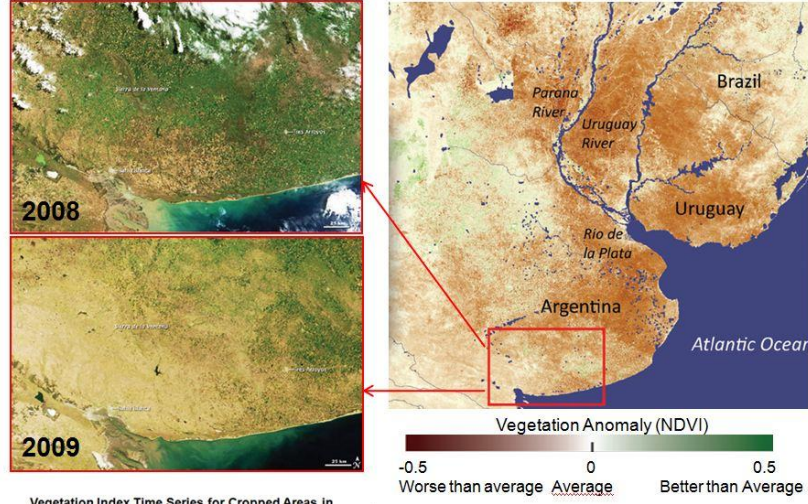
- **Crop condition monitoring. (monthly)**
 - **Production Forecast (season)**
 - **Monitoring 26 countries**
- 作物长势监测-每月
 - 主要作物作物产量监测-每季
 - 全球26个国家



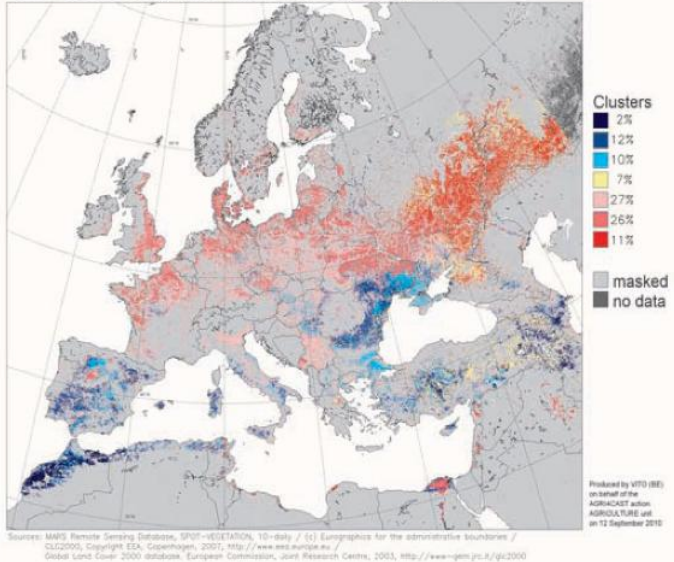
Primary Use in Crop Condition Monitoring



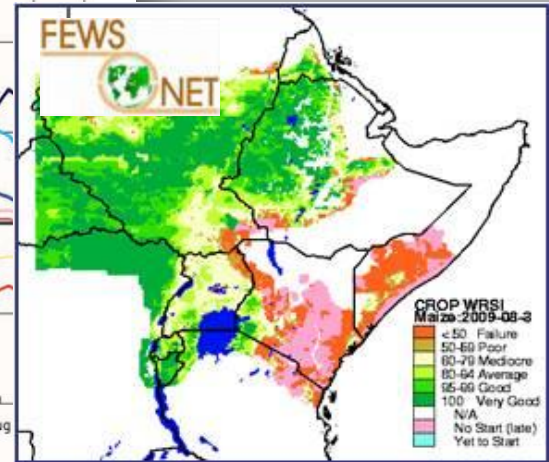
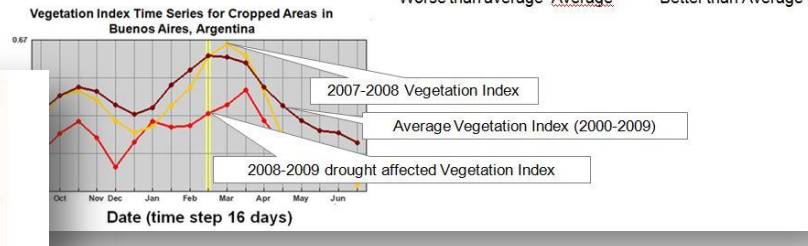
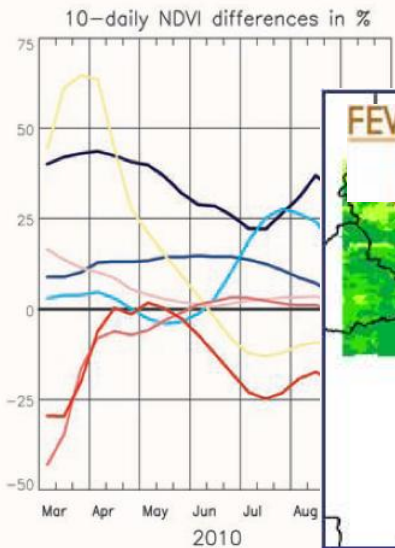
Argentina 2009 Drought Depicted with MODIS Vegetation Index Data



Clustering - Arable land
based on NDVI - rel.diff. to LTA
SPOT-VEGETATION (P) from 1 March to 10 September 2010



MARS JRC



WRSI results for maize on the Greater Horn of Africa, (Aug. 09). The extensive areas of crop failure due to drought are in Pink and red.

GLAM: GLObal Agriculture Monitoring Project

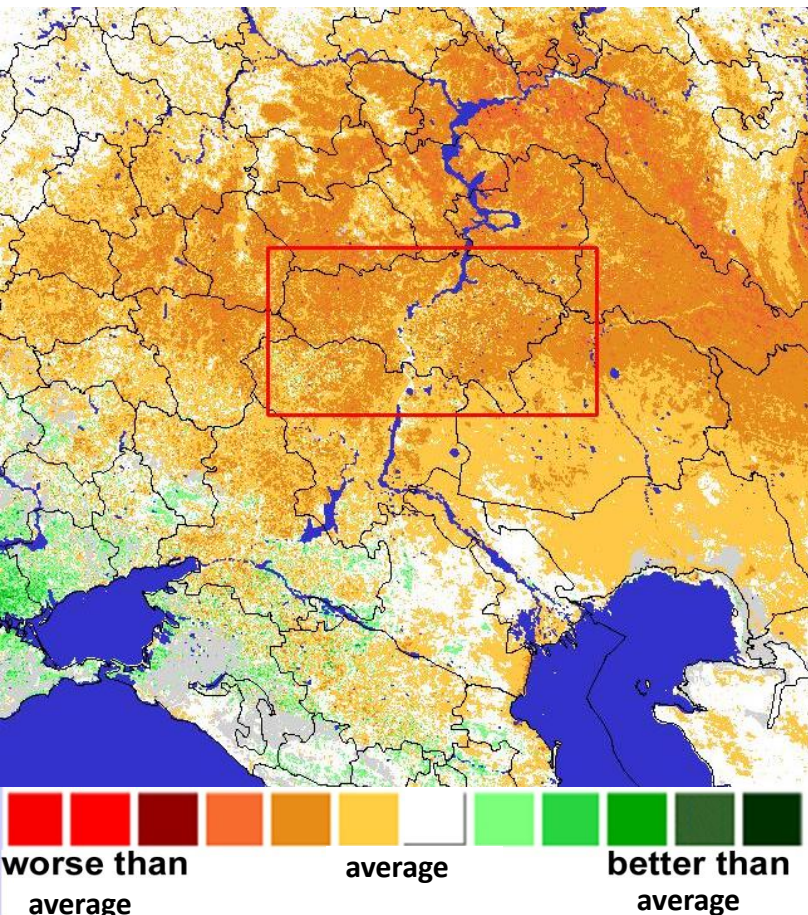
- Collaboration between NASA, USDA-FAS, UMD and SDSU
- Project aim:
 - Enhance global agricultural monitoring and the crop production estimation capabilities of the FAS through use of NASA's moderate resolution satellite data
- Contribution to the International GEO Agricultural Monitoring Task - with considerable visibility and societal benefit

Becker-Reshef, I., Justice, C., Sullivan, M., Vermote, E., Tucker, C., Anyamba, A., Small, J., Pak, E., Masuoka, E., Schmaltz, J., Hansen, M., Pittman, K., Birkett, C., Williams, D., Reynolds, C., & Doorn, B. (2010). Monitoring Global Croplands with Coarse Resolution Earth Observations: The Global Agriculture Monitoring (GLAM) Project. *Remote Sensing*, 2, 1589-1609

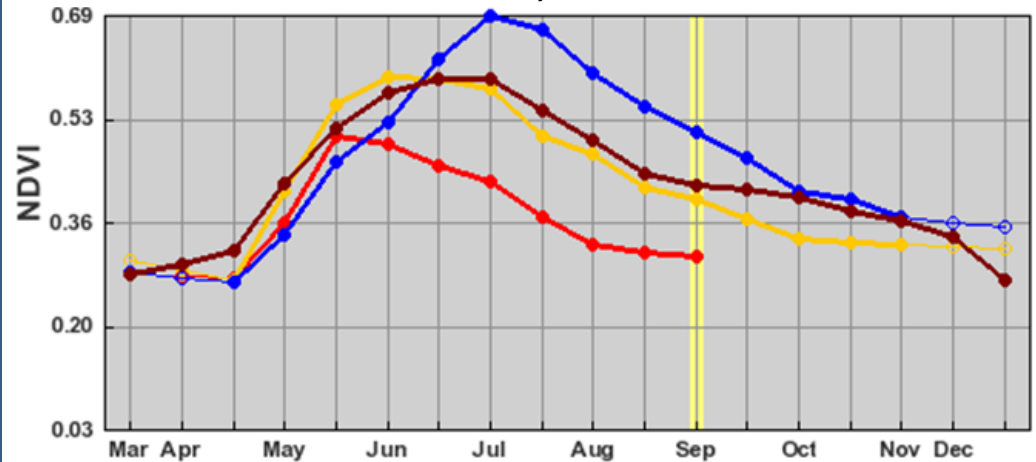


Example of Utility of the GLAM MODIS NDVI DBMS to Track Current Drought Impact on Crops in Russia

NDVI Anomaly Image, Volga District, Russia ; June 26- July11, 2010



Vegetation Index Time Series for Cropped Areas in Saratov Oblast, Russia



Date (time step 16 days)

- Current Season (2010)
- 2005, (average yield season)
- 2003, (high yield season)
- Mean NDVI curve (2000-2008)

MODIS Rapid Response Interface with FAS Crop Explorer

The screenshot shows the USDA Crop Explorer interface. At the top, it displays the USDA logo and the text "United States Department of Agriculture Foreign Agricultural Service". Below this is a banner with the text "Crop Explorer". The interface is divided into several sections. On the left, there is a "Toolbox" section with a date selector set to "r13c23" (08/04/08) and a "7-2-1 Composite (SWIR/NIR/RED)" option. Below this are two satellite image thumbnails labeled "Terra (AM)" and "Aqua (PM)", both with a pixel size of "250m | 1km | 2km". A yellow arrow points from the "True Color" label to the "Terra (AM)" image. Below these are "NDVI Images" for both "Terra NDVI" and "Aqua NDVI", also with a pixel size of "250m | 1km | 2km". In the center, there is a "MODIS Image Gallery" section with a map of Africa and a date selector set to "8/4/2008". Below the map, it says "(MODIS Image Archive is available from 05/20/2008)" and "Select a date to view the past MODIS data". There are input fields for "8", "4", and "2008", and a "Go" button. Below this is a "Download Images" button. On the right, there is a "Previous Day | Next Day" link and a "Last 30 Days All Images" link.

USDA Crop Explorer
(<http://www.pecad.fas.usda.gov/cropeexplorer>)

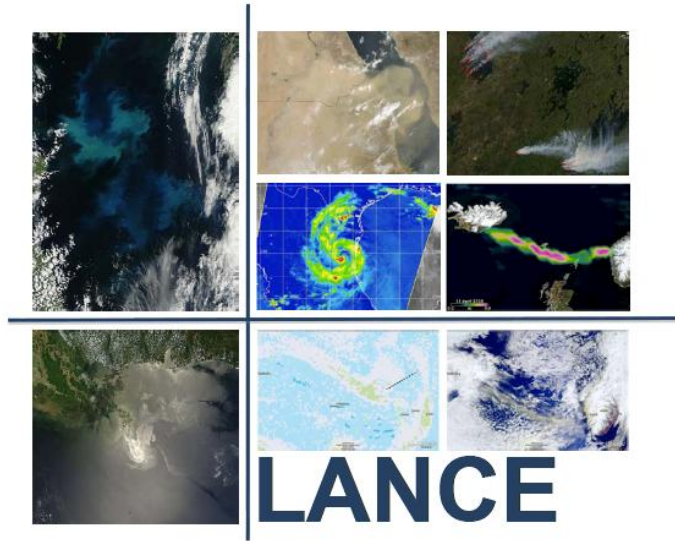
MODIS Rapid Response
(<http://rapidfire.sci.gsfc.nasa.gov>)

The screenshot shows the MODIS Rapid Response interface. At the top, it displays the USDA logo and the text "United States Department of Agriculture Foreign Agricultural Service". Below this is a banner with the text "Crop Explorer". The interface is divided into several sections. On the left, there is a "Toolbox" section. The main part of the interface is a large map of the world with a red grid overlay. A yellow box highlights a specific region in the central part of the map. Below the map, there is a link that says "Click here to add your Comments/Feedback". At the bottom, there are logos for NASA and ASAC.

- MODIS RR 250m Data fully integrated in Crop Explorer
- data are available at spatial resolutions of 250m, 500m and 1km
- two different band combination data sets are available and NDVI data set
- Rapidly accessible data allow the FAS analysts to evaluate, and assess, in near real time, the effect of disaster events on crops

LANCE: Near Real Time NASA EOS Data

National Aeronautics and Space Administration



AIRS AMSR-E MLS MODIS OMI

Near-real-time data for applications, disaster response and field campaigns

- ✓ Products within 3 hours of observation
- ✓ Highly available processing and distribution systems
- ✓ Products based on science algorithms

lance.nasa.gov

Land Atmosphere Near-real-time Capability for EOS

Providing NASA near-real-time observations to the GEO International Community

MODIS Data and Products being provided in near real time for time sensitive applications – e.g. Agricultural monitoring

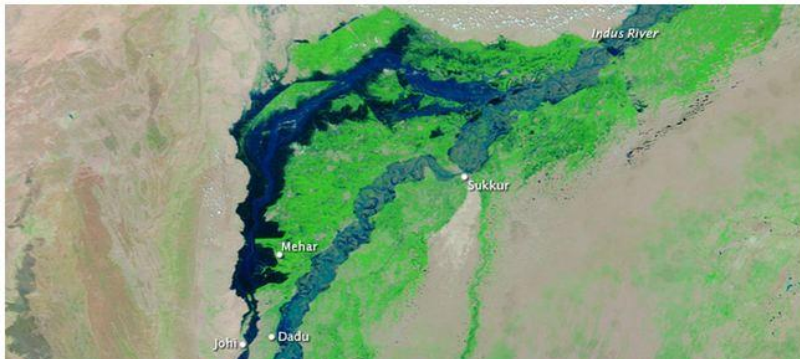
Near Real Time MODIS data from LANCE for Monitoring Floods in Pakistan



MODIS RR Image July 19, 2010



MODIS RR Image August 11, 2010



MODIS RR Image September 7 2010

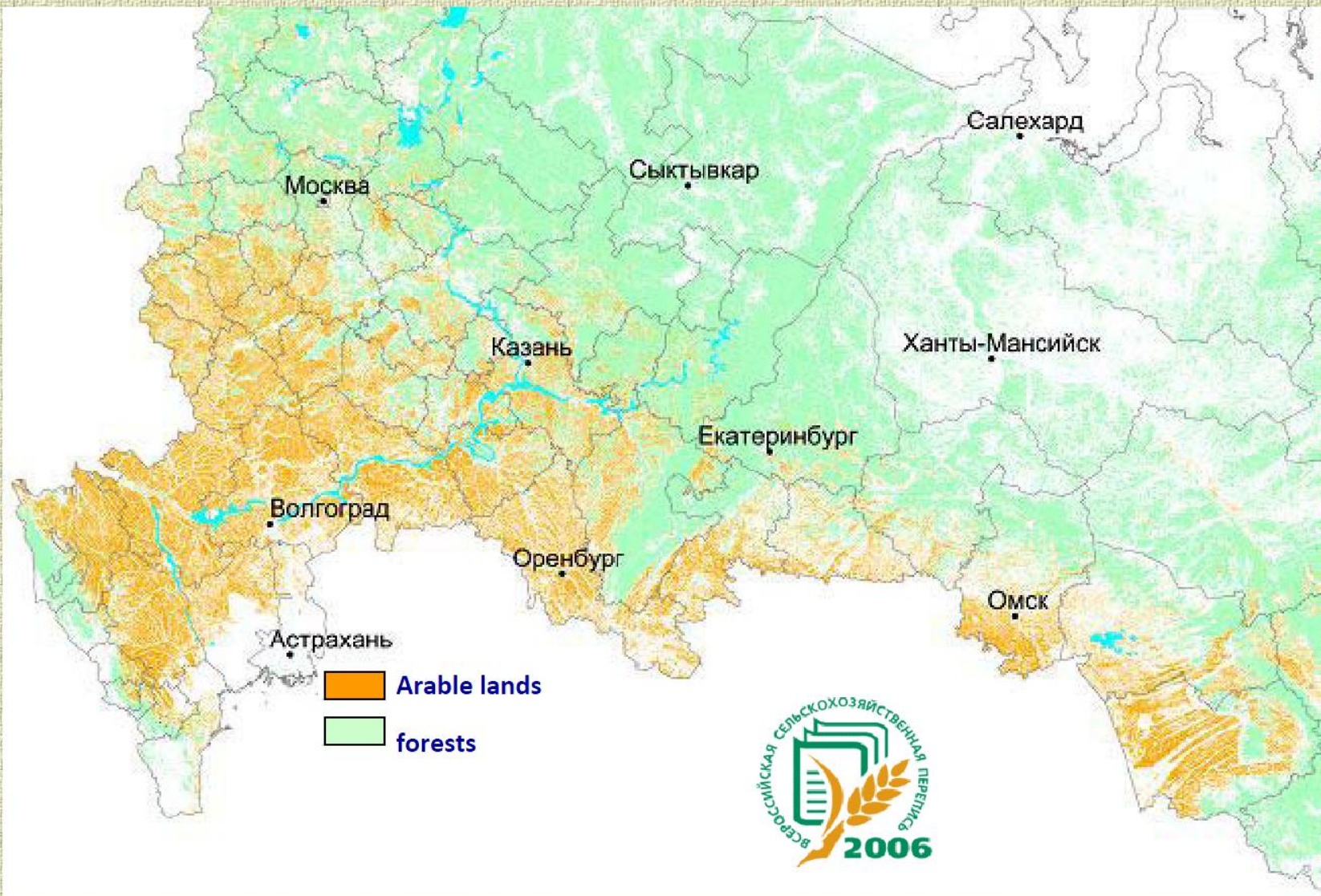
images span a 50-day period from July 19th – Sept 7th

3.6 million hectares of productive farmlands have been destroyed due to floods

Major threats to food security as seeds, crops and incomes are all severely affected.

Rapidly accessible data is critical for effective monitoring and to evaluate, and assess, in near real time, the effect of disaster events on crops

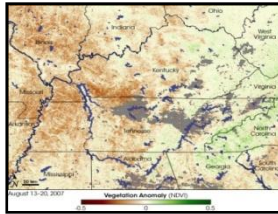
Arable lands detection based on MODIS data



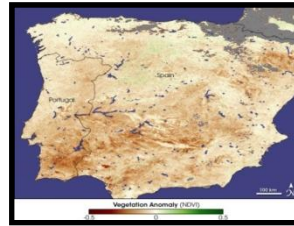
Distribution of Crop Failures due to Droughts

Depicted by NASA MODIS Imagery from the GLAM Project

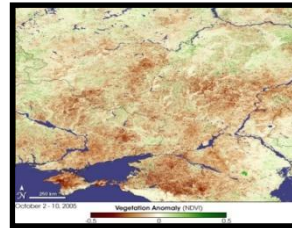
Drought in US Southern Plains, 2007



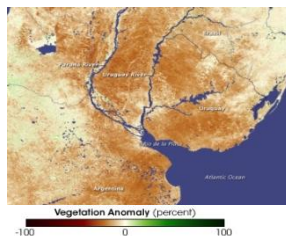
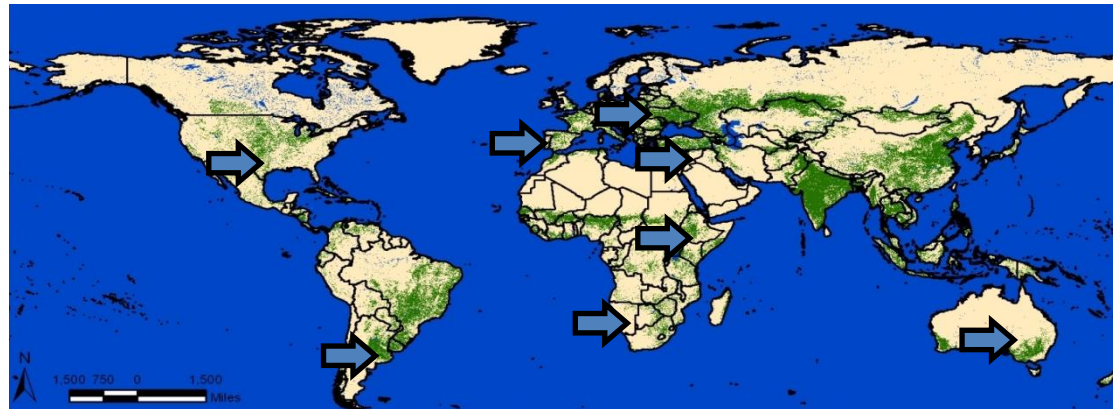
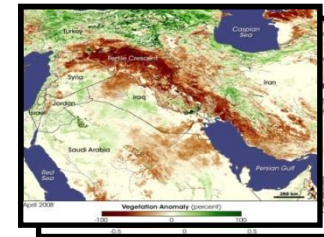
Drought on Iberian Peninsula, 2005



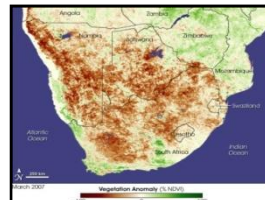
Drought, Ukraine, 2005



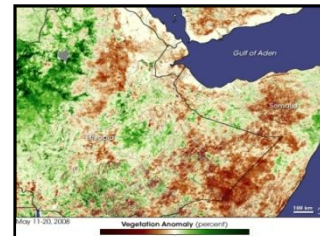
Drought in Fertile Crescent, 2008



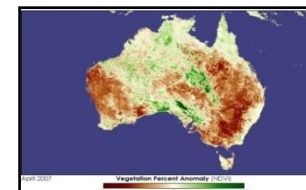
Drought in Argentina 2009



Drought in Southern Africa, 2007




Drought in Ethiopia, 2008



Drought in Australia, 2007

Increasing International Attention is being given to
Global Food Security



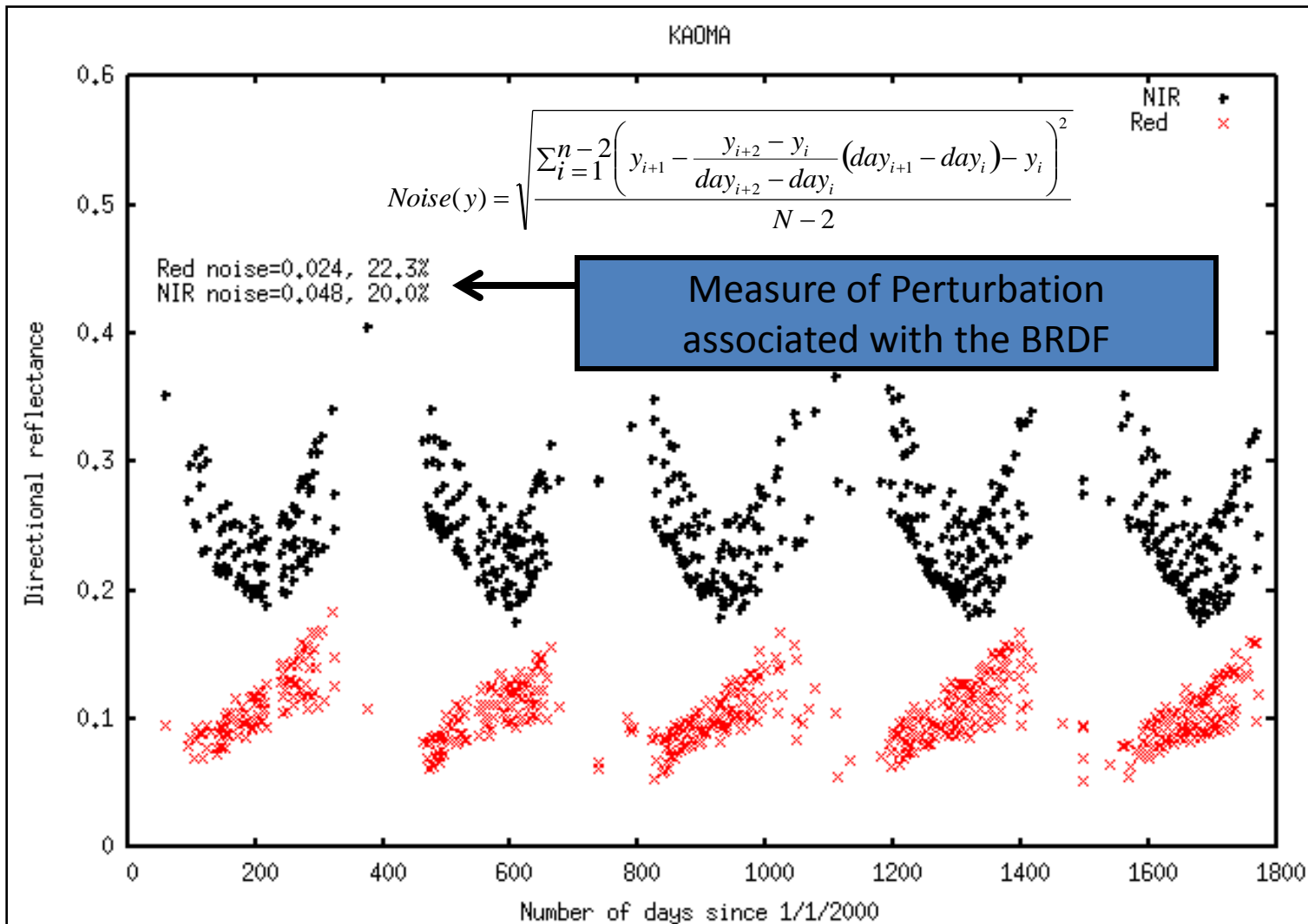
GLAM Research: Winter Wheat Yield Forecasting using MODIS Coarse Resolution CMG data

Objective: Using MODIS, high quality, coarse resolution daily time series to develop a simple generalized and transferable model for assessing winter wheat yields prior to harvest

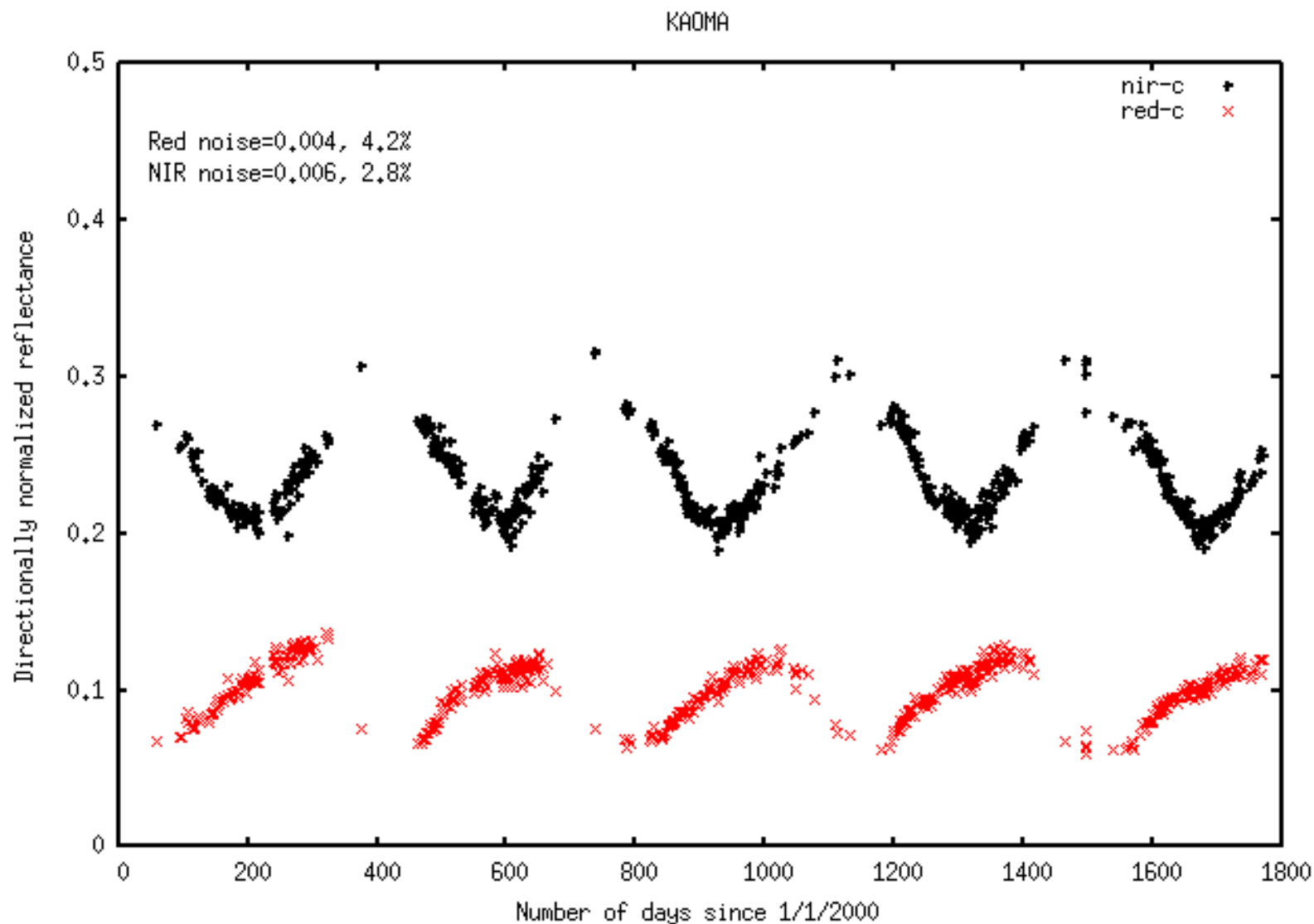
Becker-Reshef I, Vermote E, Lindeman M, Justice C. 2010. In Remote Sensing of Environment, 114, 1312–1323.

Example of BRDF effect observed over Savanna

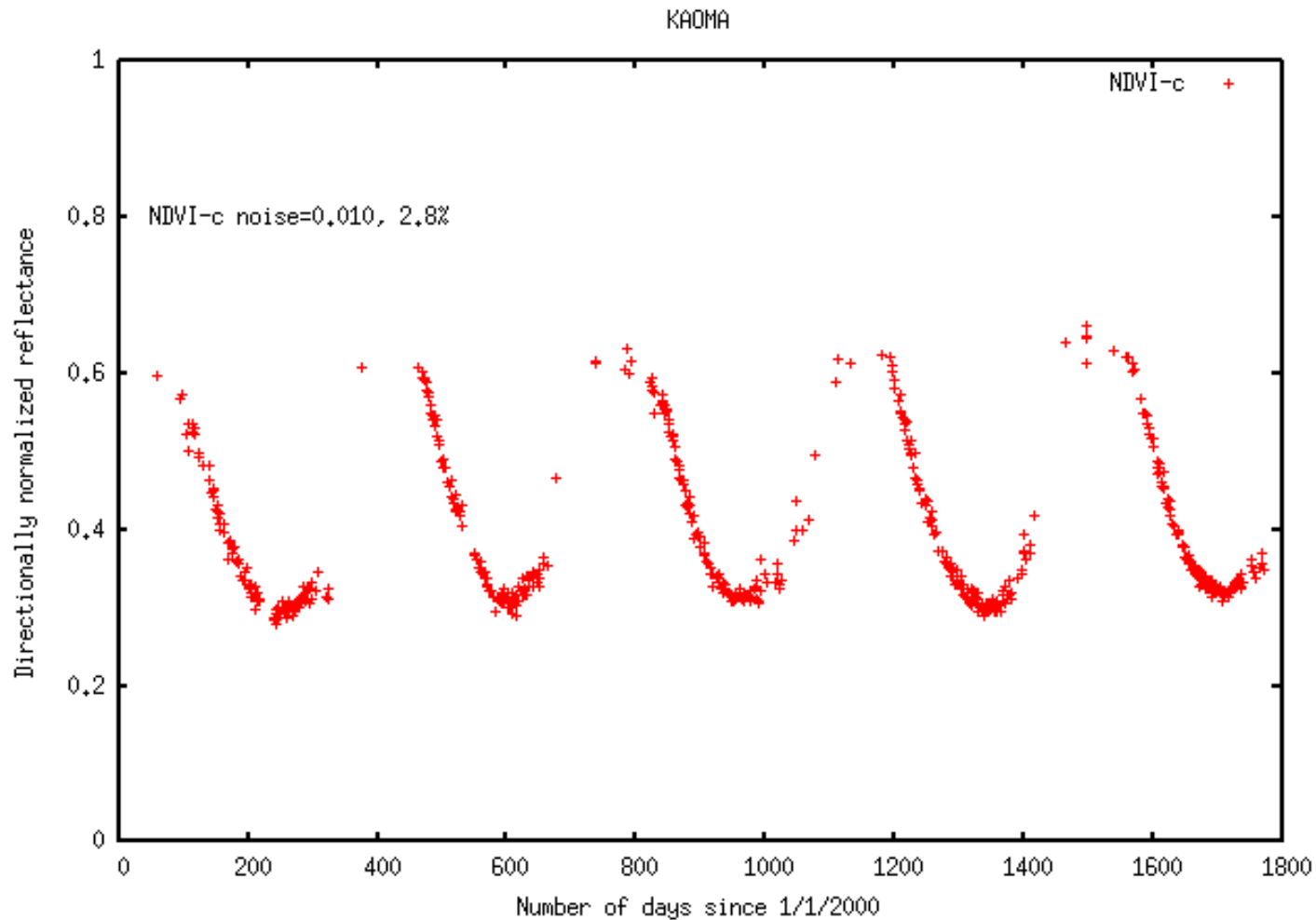
Time series (2000 to 2004) MODIS CMG daily Red and Nir reflectance data over a southern Africa Tropical Savanna site



data after BRDF Correction



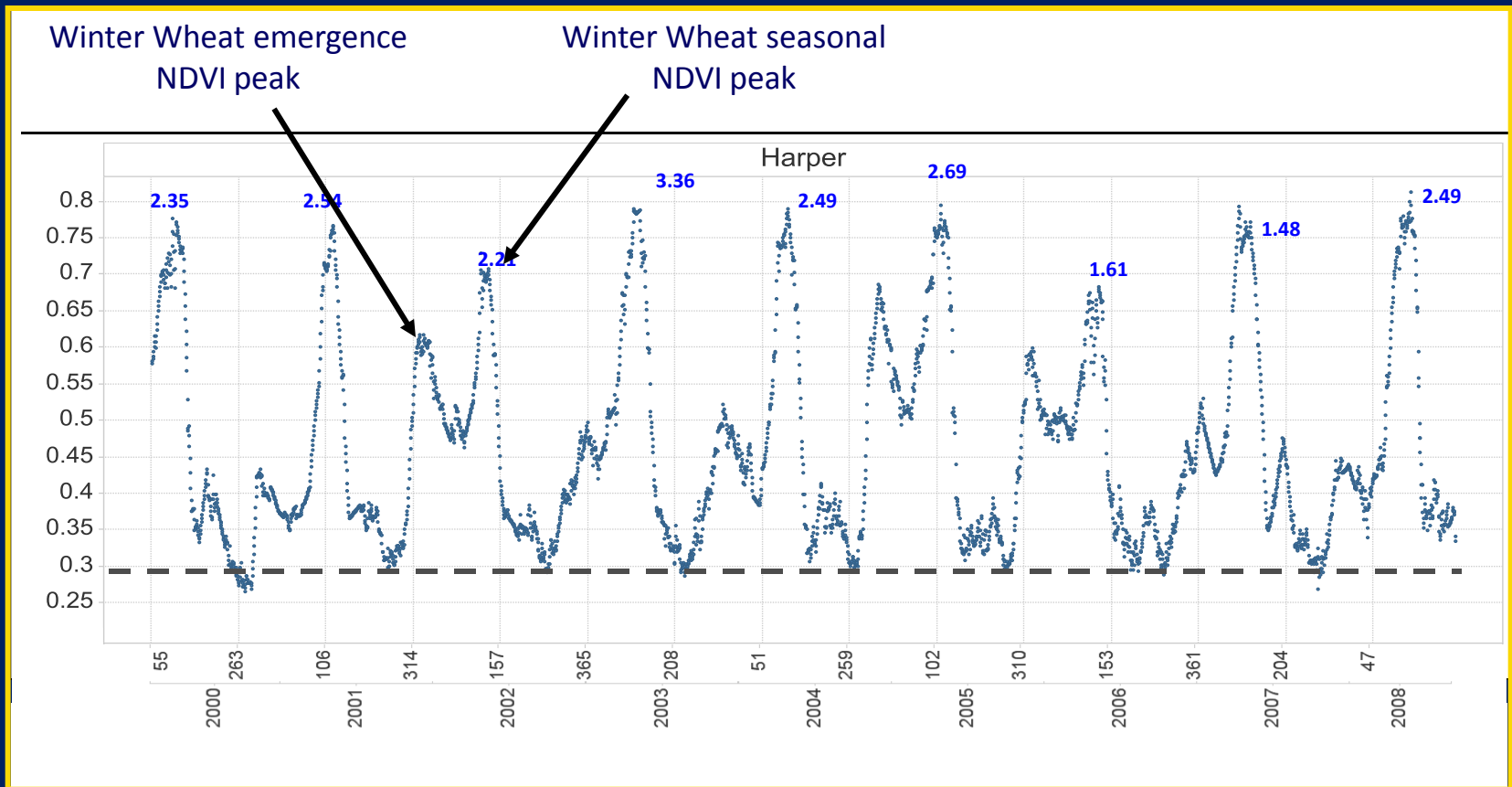
Vegetation index (NDVI)



Vermote, E., Justice, C.O., & Breon, F.M. (2009). Towards a Generalized Approach for Correction of the BRDF Effect in MODIS Directional Reflectances. *Ieee Transactions on Geoscience and Remote Sensing*, 47, 898-908

Kansas Harper County daily 0.05 degree NDVI Time Series for Winter Wheat Pixels

Blue numbers: yield in T/ha

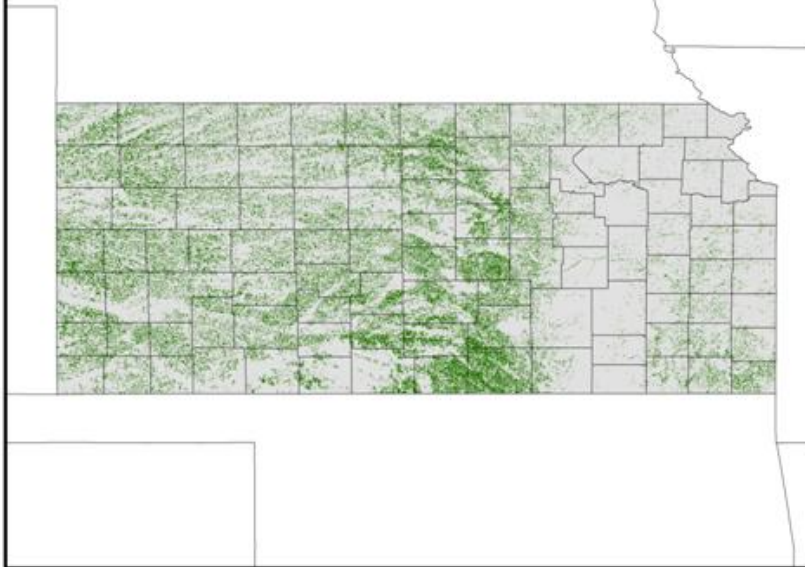


Maximum Adjusted NDVI (MA_NDVI)

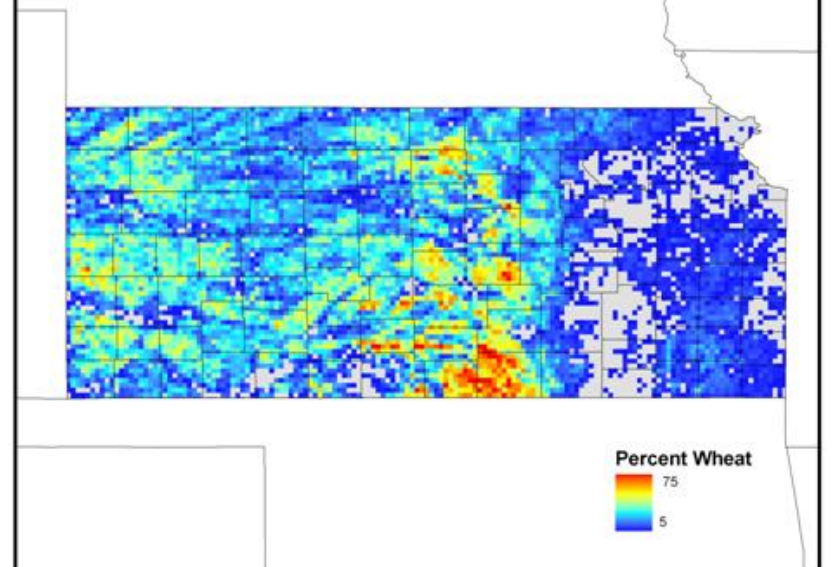
$$MA_NDVI_y = VI_{\max 95,y} - \frac{1}{N} \left[\sum_{y=1}^N VI_{\min 5,y} \right]$$

Creating a Winter Wheat Percent Winter Wheat Mask From USDA NASS Crop Masks (CDL)

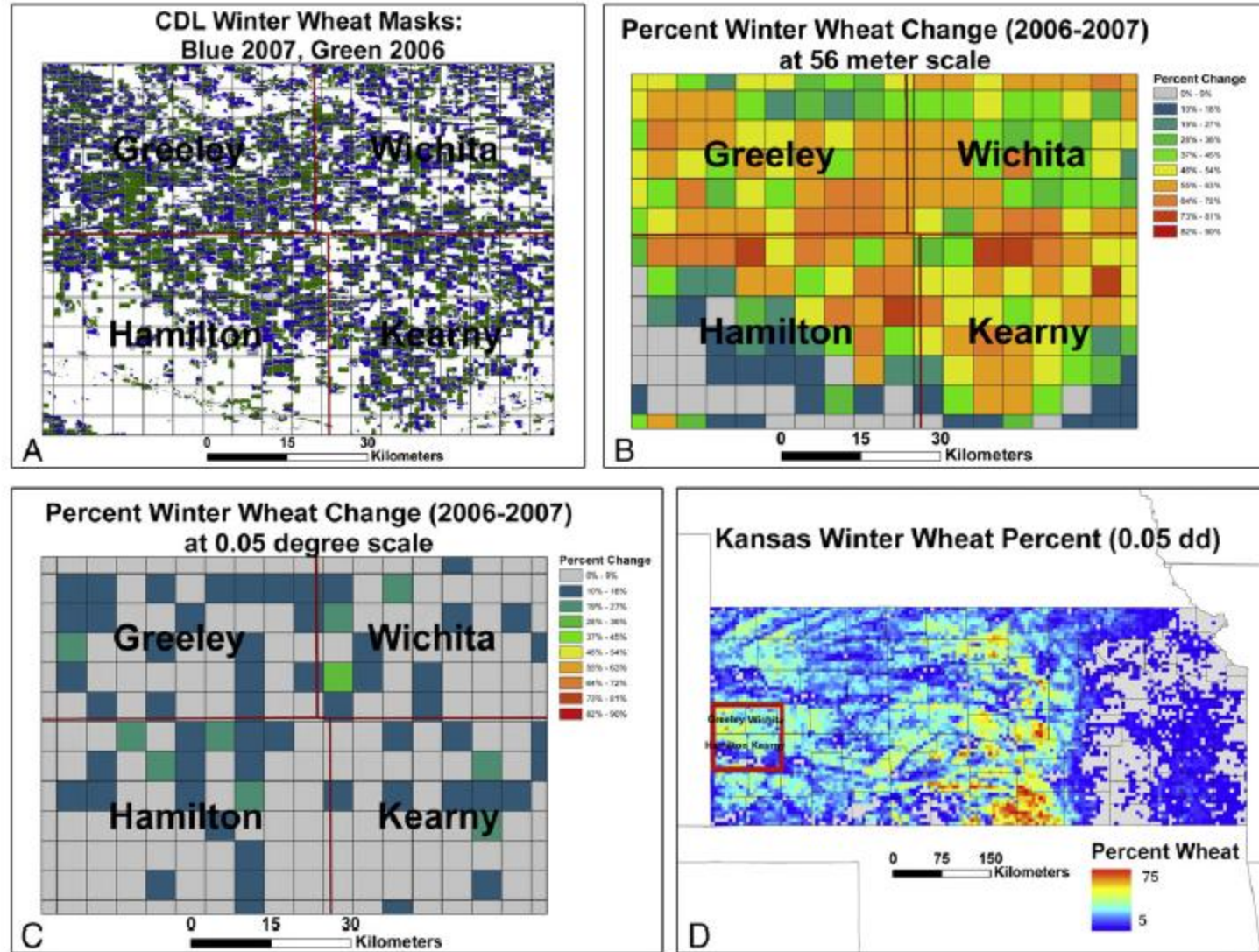
Winter Wheat NASS CDL (AWiFS, 57m)



Winter Wheat Percent (0.05 dd)



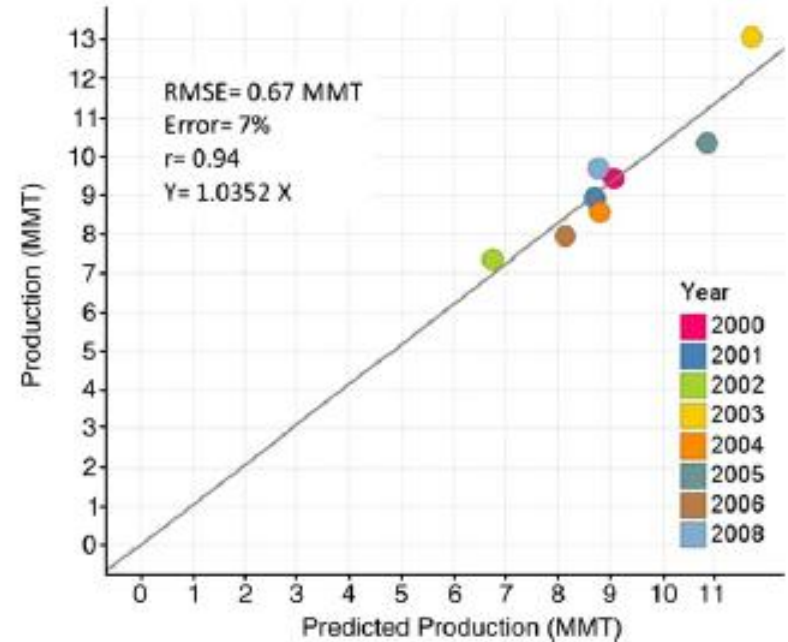
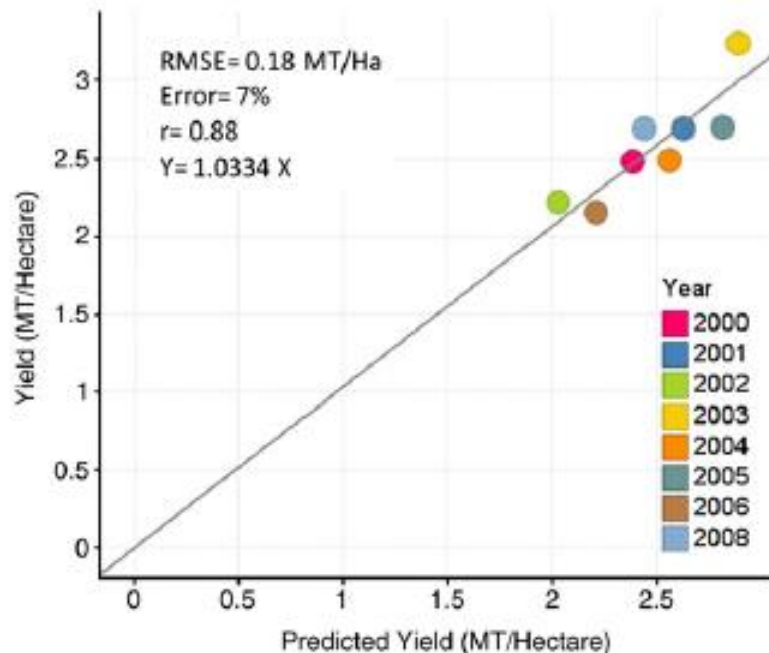
Per pixel percent wheat change at the 56m and 0.05 degree scales



at the 0.05° scale, the per pixel percent wheat remains relatively constant with the large majority of pixels varying less than 20%.

Kansas Results:

Kansas Model Estimates vs. USDA NASS Crop Statistics

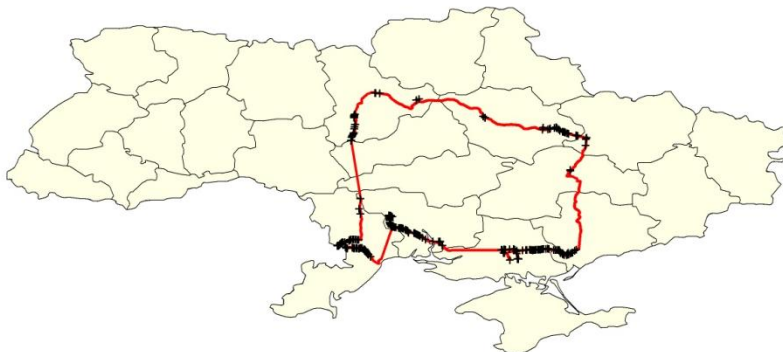


Model Extendibility: Ukraine

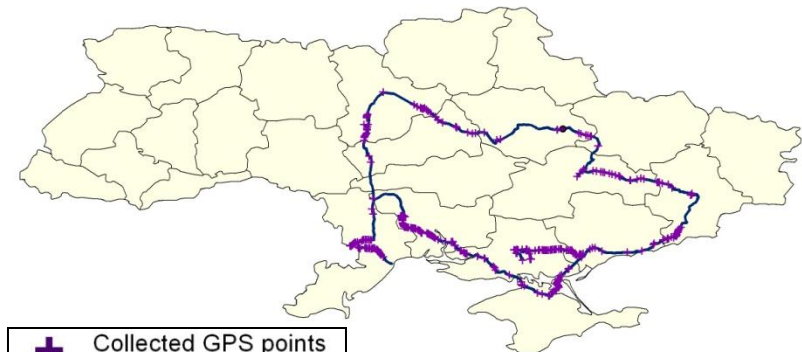
Investigate the feasibility of extending a Kansas winter wheat production forecasting model to Ukraine



Ukraine USDA-FAS Crop Tour 2009



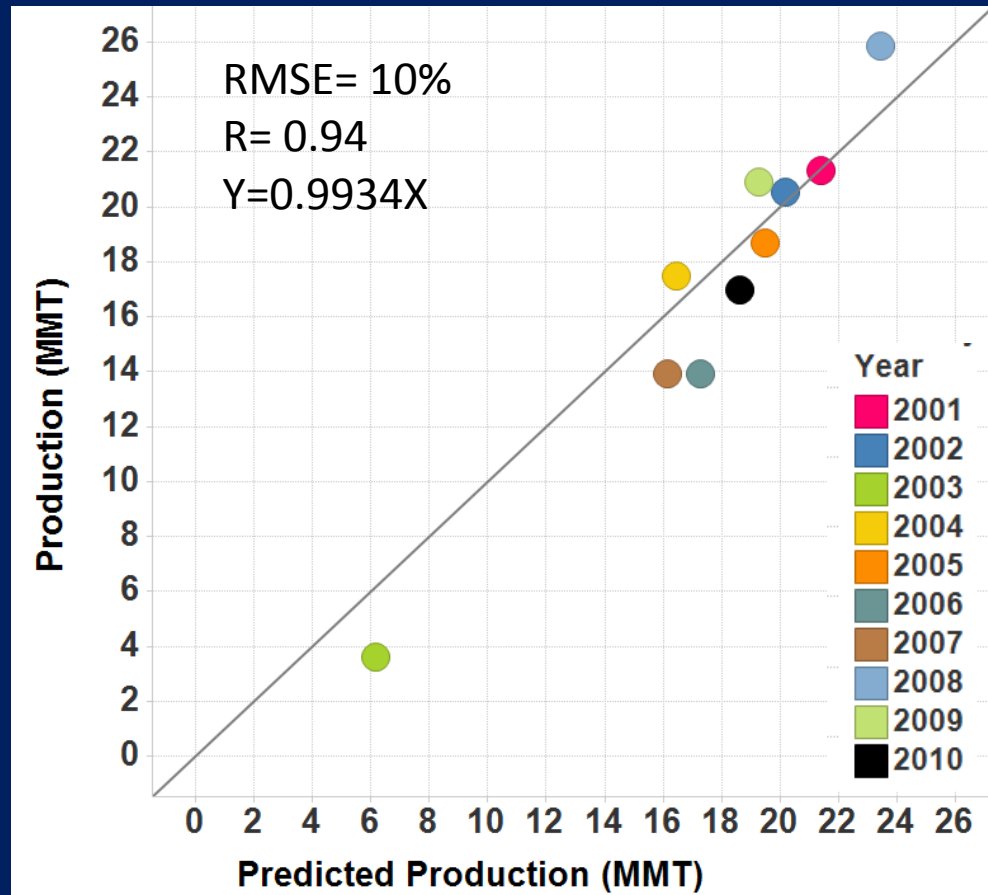
Ukraine USDA-FAS Crop Tour 2010



+ Collected GPS points
of winter wheat
— Crop Tour Track

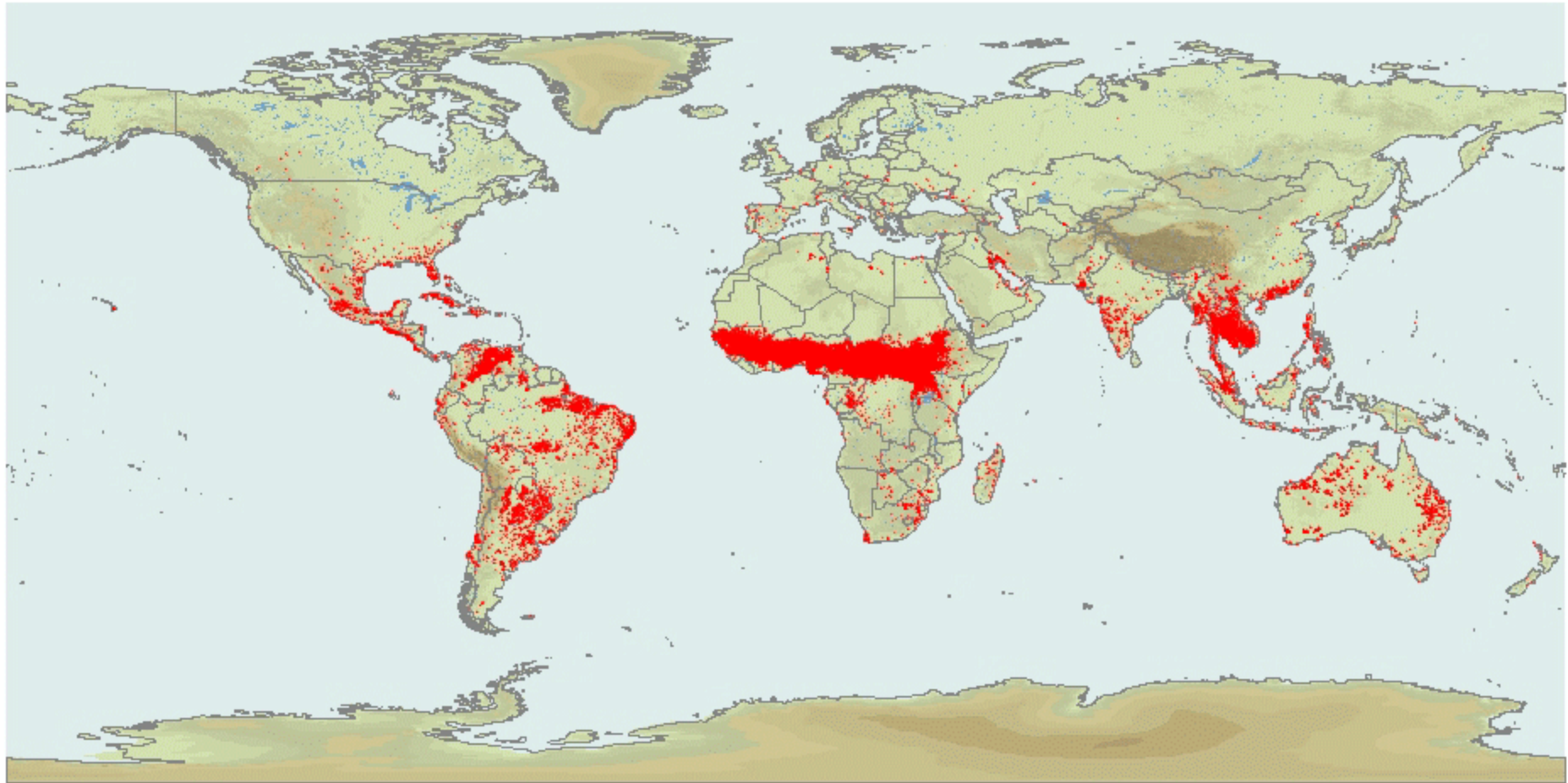
Model Results in Ukraine:

Model estimated production vs. Ukrainian State Statistical Committee Crop Statistics



The model forecast 6 weeks prior to beginning of harvest was within 10% of final reported production.

MODIS Global Daily Active Fire Product



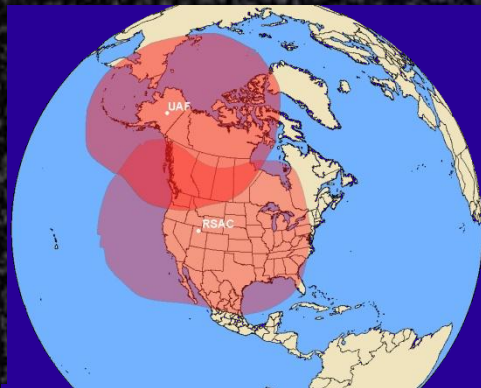
JANUARY FEBRUARY MARCH APRIL MAY JUNE JULY AUGUST SEPTEMBER OCTOBER NOVEMBER DECEMBER



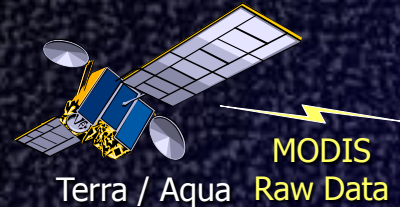
- MODIS Active Fire Detections
- World Countries

Active fires are detected using MODIS data from the Terra satellite.
Source: MODIS Rapid Response <http://rapidfire.sci.gsfc.nasa.gov>
Web Fire Mapper <http://maps.geog.umd.edu>

USFS DB Station NRT Capability



USFS-RSAC/UAF-GINA
Direct Broadcast Coverage



Terra / Aqua
MODIS Raw Data



TDRSS

MODIS Raw Data



USFS-RSAC
Direct Readout

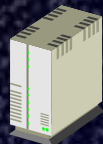


UAF-GINA
Direct Readout



White Sands, NM

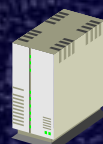
MODIS L0 Data
($< 1/2$ hour)



USFS-RSAC
Rapid Response System

Image & Active Fire
Detection Processing

MODIS L0 Data
($< 1/2$ hour)



UAF-GINA
Rapid Response System

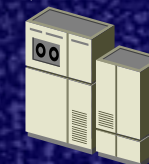
Image & Active Fire
Detection Processing

MODIS L0 Data



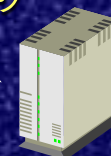
GES DAAC
NASA/GSFC

MODIS Land
Product
Distribution @
LP DAAC
(~ 1 Week)



NOAA MODIS
Real Time
Processing System

MODIS L0
(~ 3 hours)



NASA/GSFC
Rapid Response System

Image & Active Fire
Detection Processing



RSAC Direct Readout

**S. California Fires
October 27, 2003**

This map displays the distribution of fires across Southern California on October 27, 2003. The map includes major cities such as Los Angeles, San Diego, San Bernardino, and San Jose. It also shows major highways like I-5, I-10, I-15, and I-805. Red dots represent individual fire locations, while yellow dots represent the perimeters of larger fires. The map shows a high concentration of fires in the Los Angeles basin and the San Diego area, with smaller fires scattered throughout the region.

S. California Fires October 27, 2003

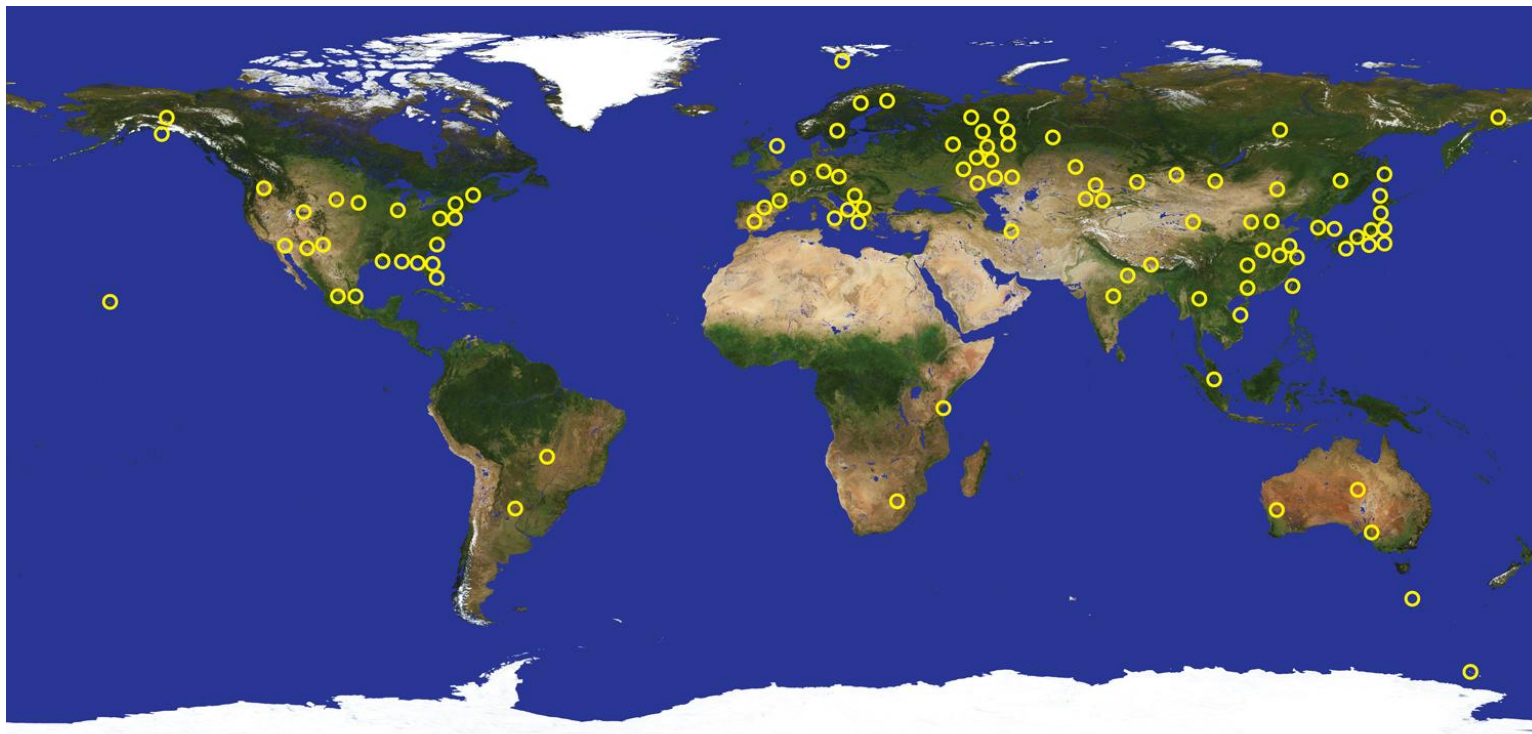
Over 200 EOS direct readout ground systems world-wide

Cover over 80% of Earth's land mass

50% owned by government agencies and organizations

35% owned by educational institutions, 15% owned by the commercial sector

Over 30 countries have DB reception capability



- 100% of DB sites use at least one of NASA's DR algorithms/tools
 - 85% of these ground stations support real-time applications

Supporting over 3000 users

Fire Information for Resource Management System (FIRMS)

- Developed at UMD and operated with great success
- Transitioned to operational partner UN-FAO (GFIMS)



Supporting Environmental/Fire Research and Management

Strategic Fire Management:
to control or suppress fires

Establish fire record
to help formulate
fire policy

Early Warning Disaster Management

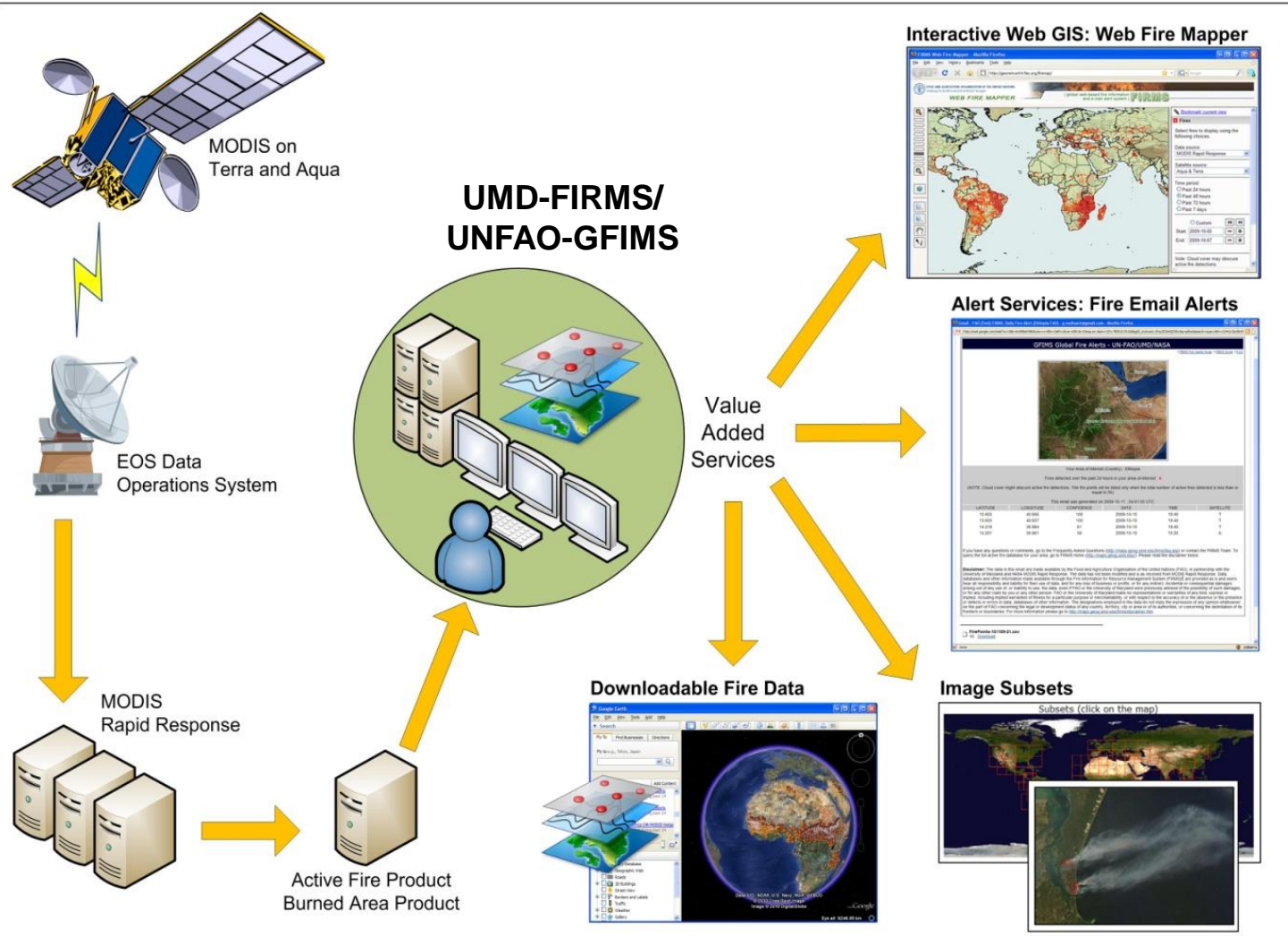
Ecological Monitoring

Validating fire risk maps

Prioritization of resources
Analyze fire responses
& staffing levels

Modeling fire emissions

Identify poaching activity





Transitioning FIRMS to the UN Food and Agriculture Organization, Rome



- The FAO system, called Global Fire Information Management System was launched in August 2010
- Reaching more users through the UN system
- FIRMS data being integrated into a number of UN applications, for example the report on air quality in Cairo as a result of rice straw burning in the Nile delta.
- Creating country fire reports, which can help investigate fire activity in nations that don't have their own monitoring systems.

Mission Report
Monitoring the Skies over Cairo
Issues of Burning Rice Straw in the Nile Delta



Karim Abdelmalik & Peter Steele
Consultants

November 2007

Food and Agriculture Organization
of the United Nations, Cairo Egypt



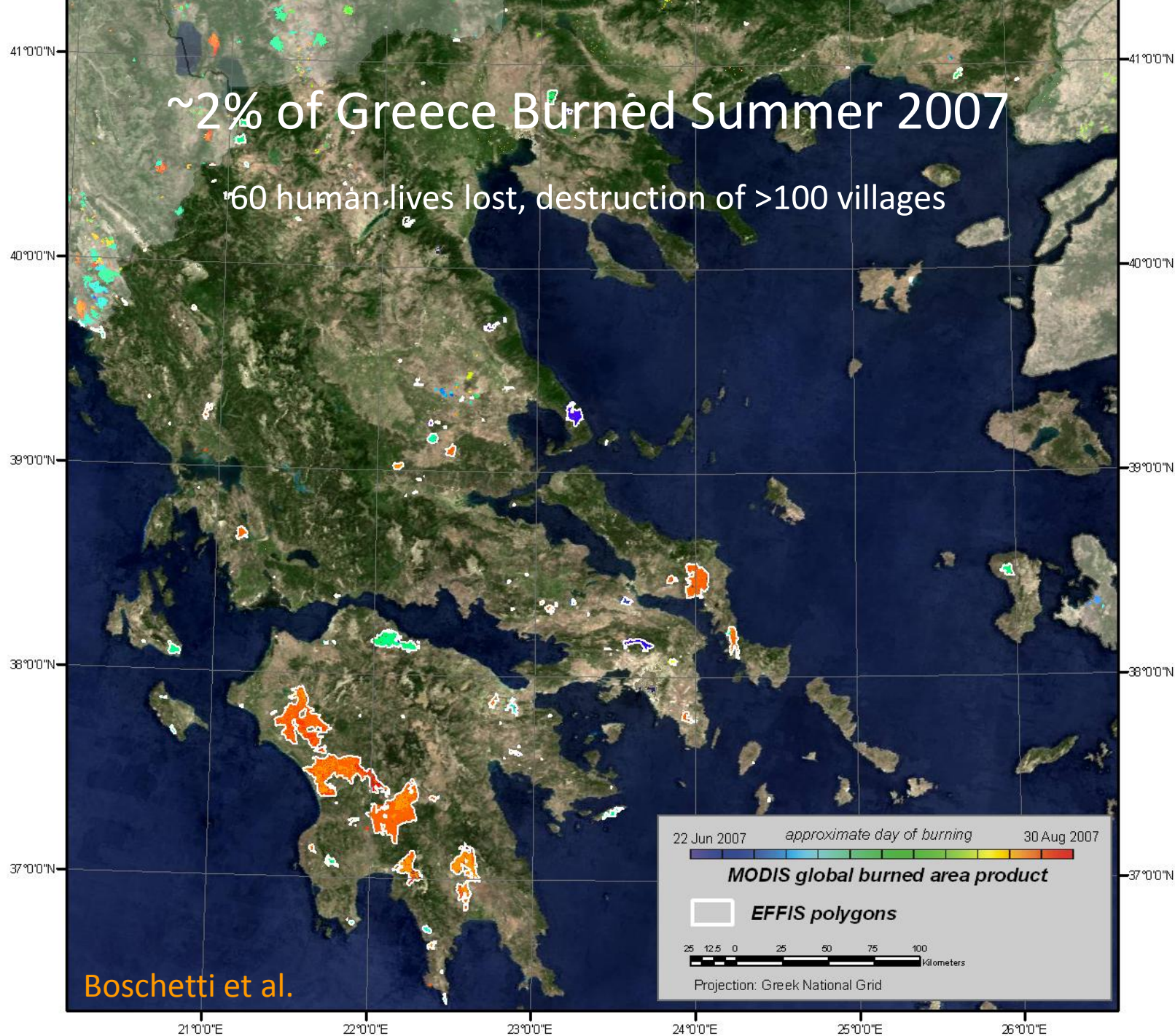
A cloud of haze hanging over Cairo.



250m MODIS: October 25, 2002

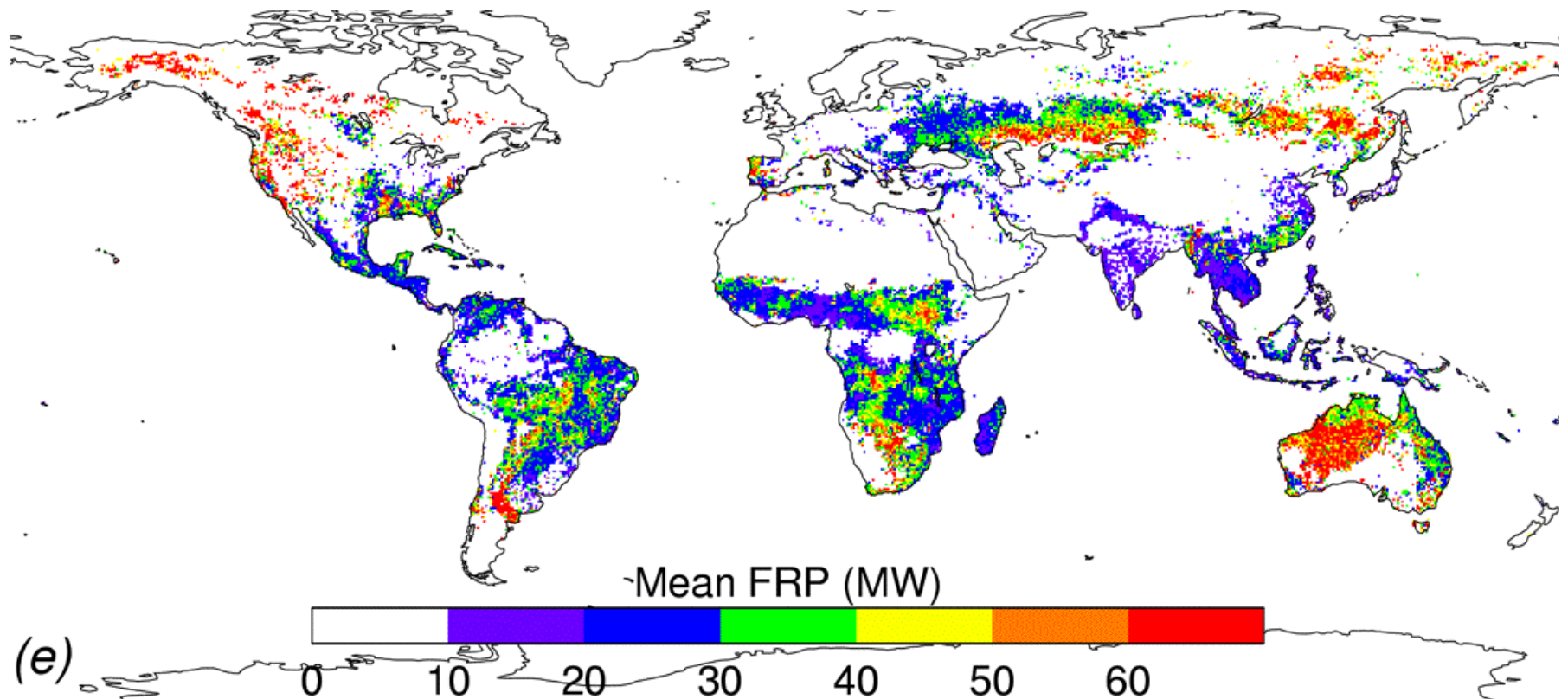
~2% of Greece Burned Summer 2007

60 human lives lost, destruction of >100 villages



Boschetti et al.

Global Characterization of active fire properties



Mean Fire Radiative Power

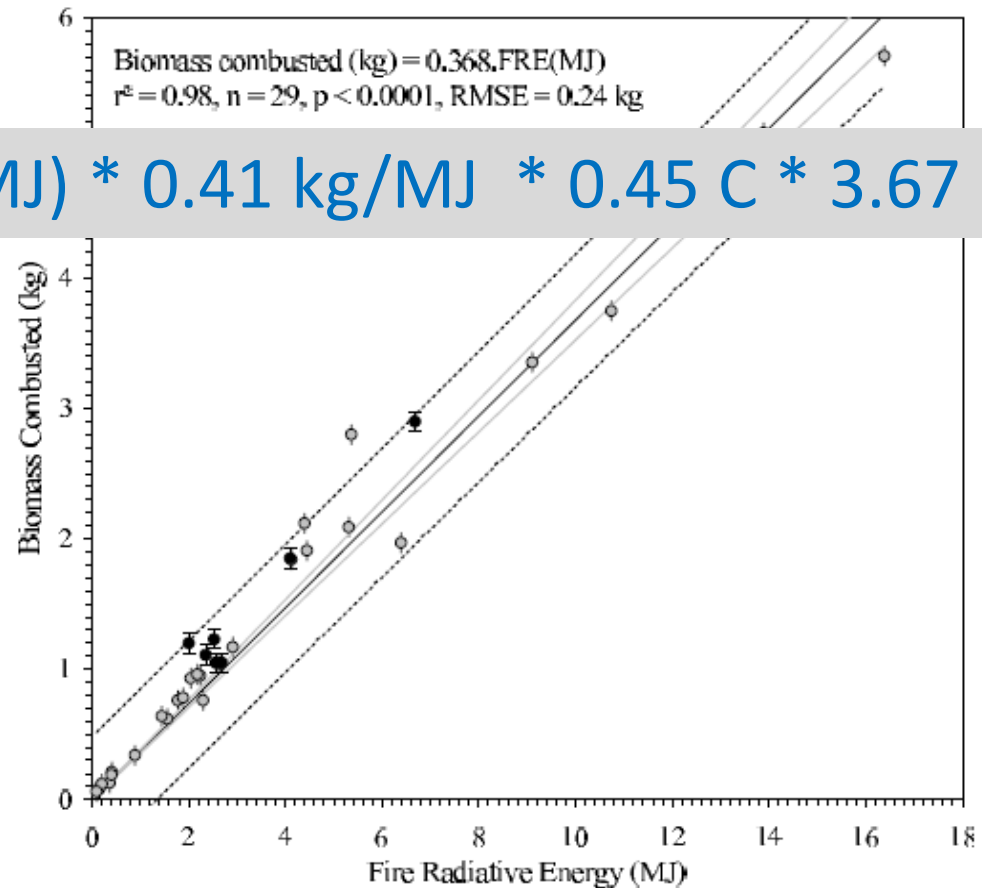
Radiant heat energy liberated per unit time

(Terra MODIS mean ; Nov. 2001 - Oct. 2005)

Biomass Combusted and CO₂

Field experiments have demonstrated the application of biomass consumed from fire (Wooster *et al.*, 2005) and recent laboratory investigations by Freeborne *et al.* (2008) have supported the accuracy of Wooster *et al.*'s earlier work.

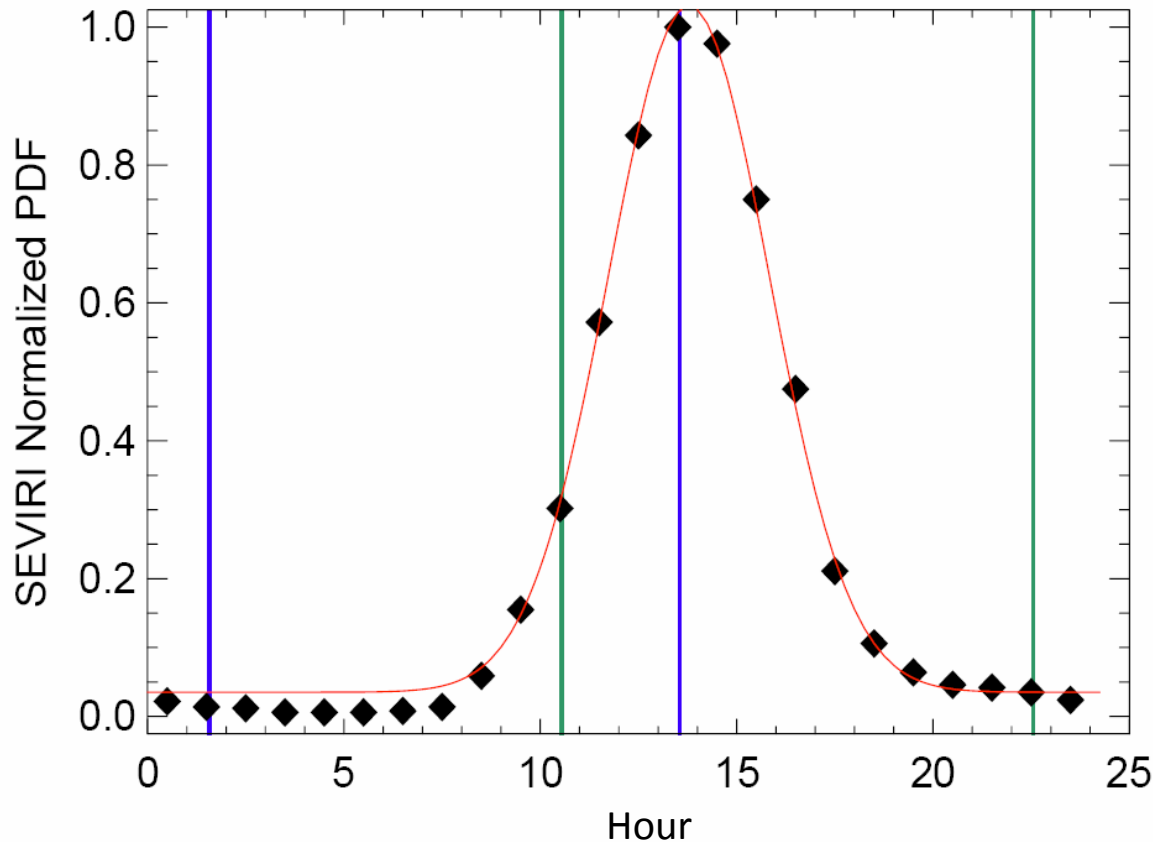
$$\text{CO}_2 = \text{FRE}(\text{MJ}) * 0.41 \text{ kg/MJ} * 0.45 \text{ C} * 3.67$$



Wooster *et al.* [2005]

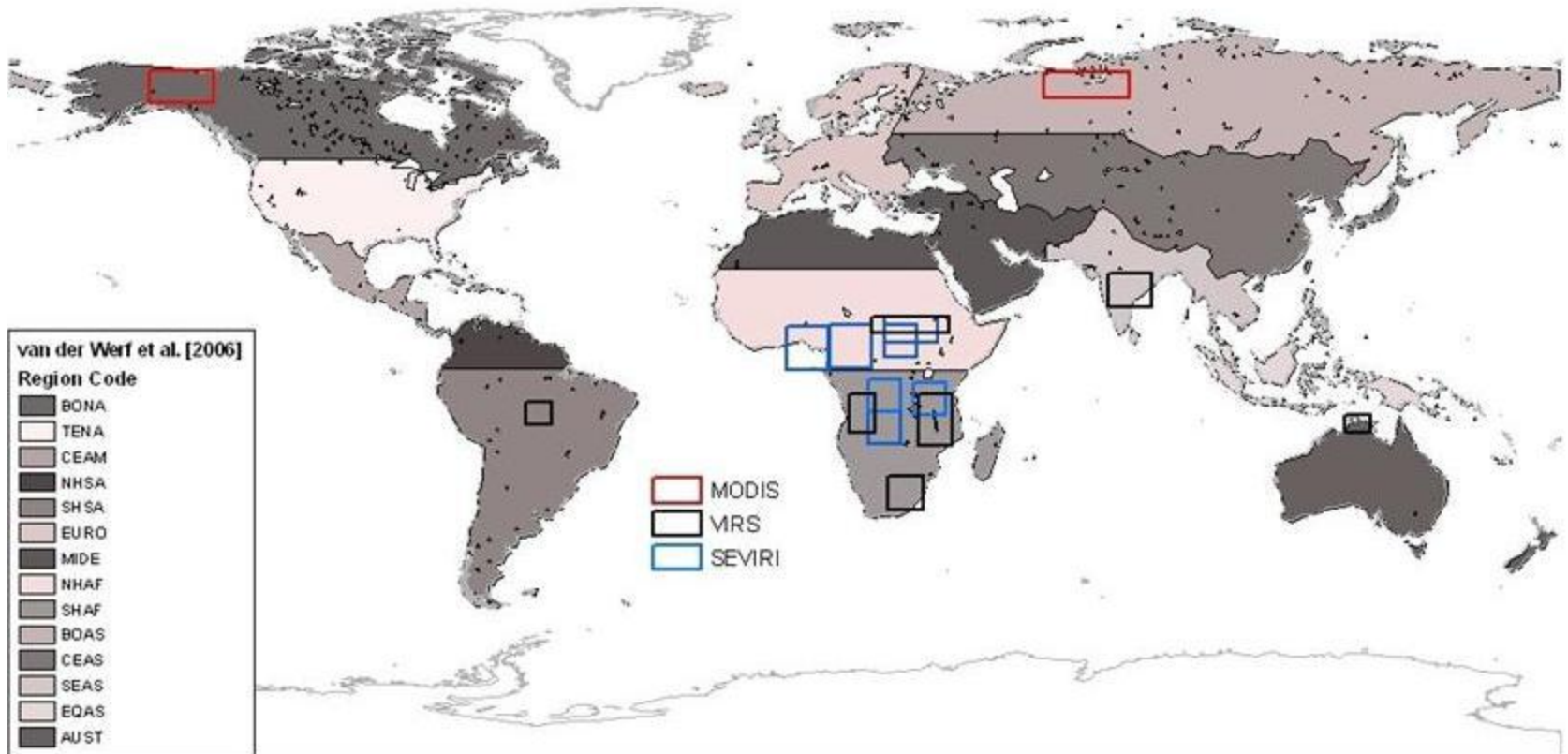
MODIS

The MODIS sensors, onboard the sun-synchronous polar-orbiting satellites Terra and Aqua, acquire four observations of nearly the entire Earth daily at 1030 and 2230 (Terra) and 0130 and 1330 (Aqua), equatorial local time.



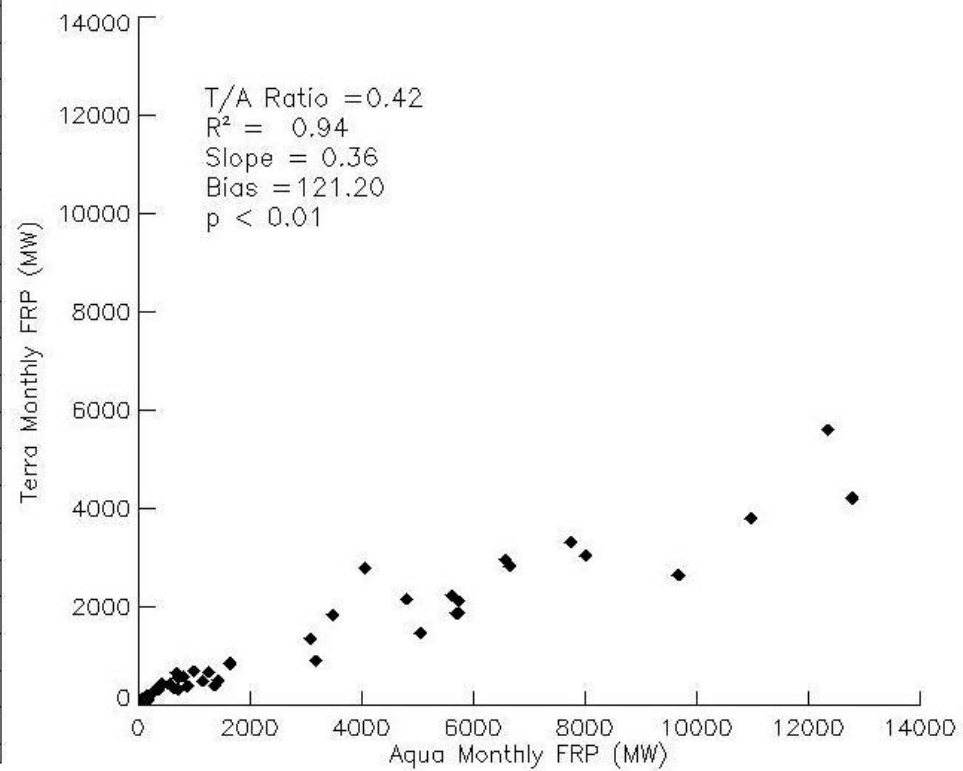
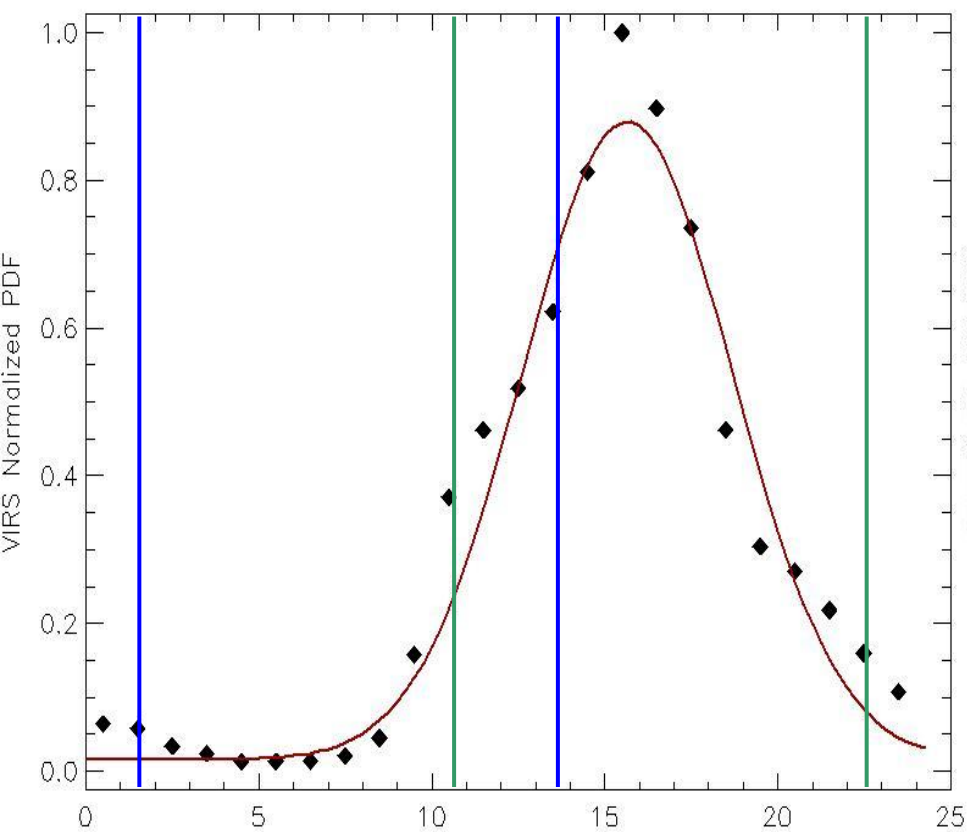
However, a current limitation is that the retrieval of fire energy from satellites is of instantaneous energy (power) over some discrete length of time and space.

FRE

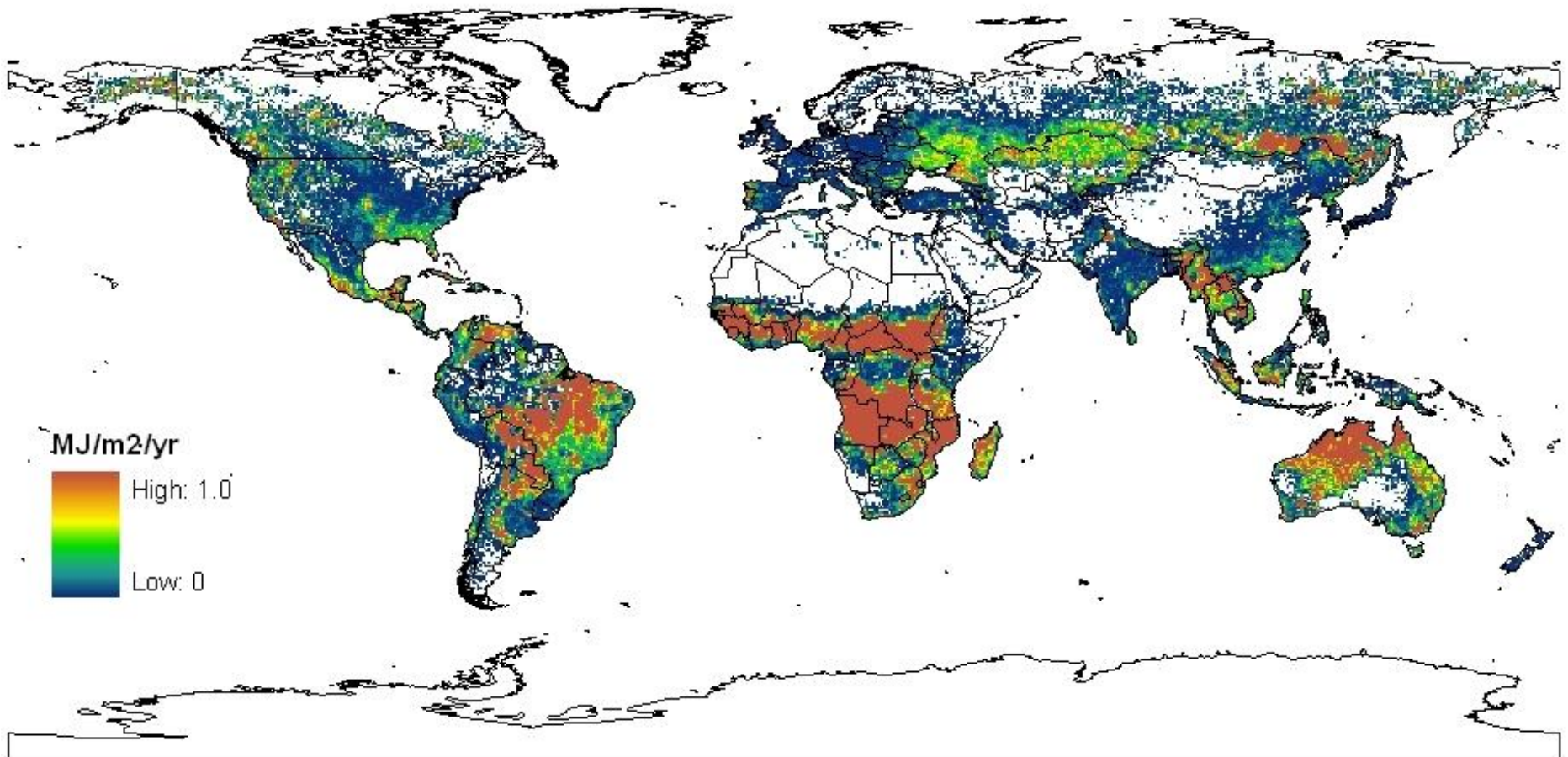


$$FRP(t) = FRP_{peak} \left(b + e^{-\frac{(t-h)^2}{2\sigma^2}} \right)$$

FRE



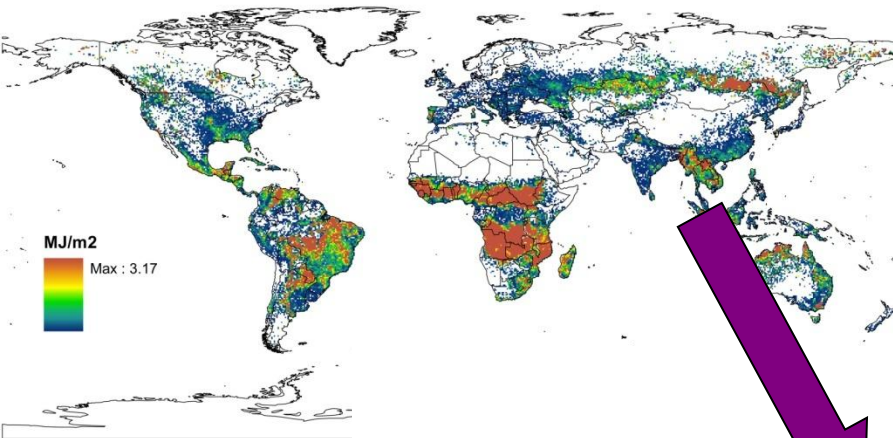
Fire Radiative Energy



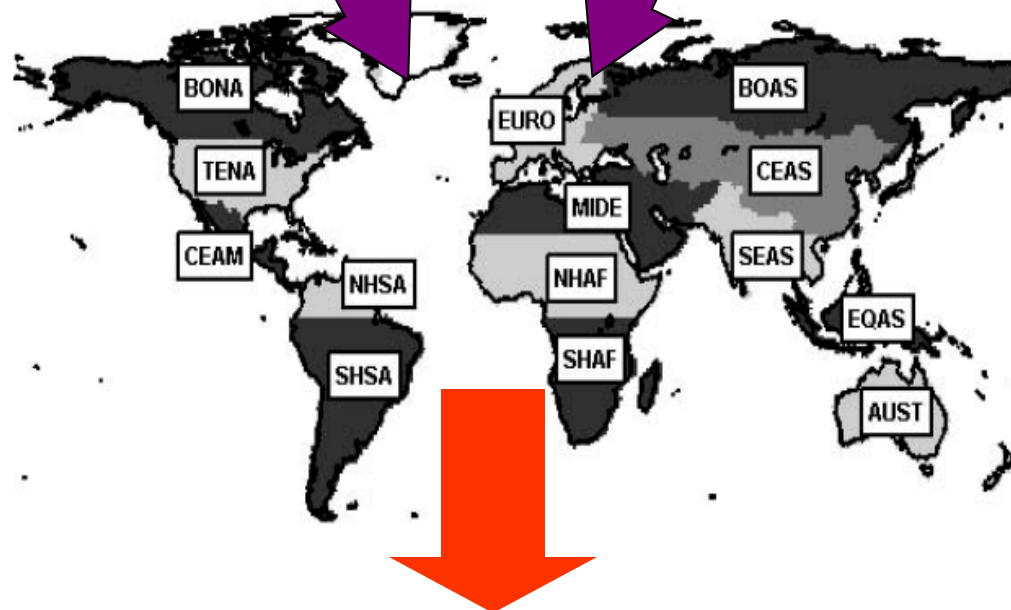
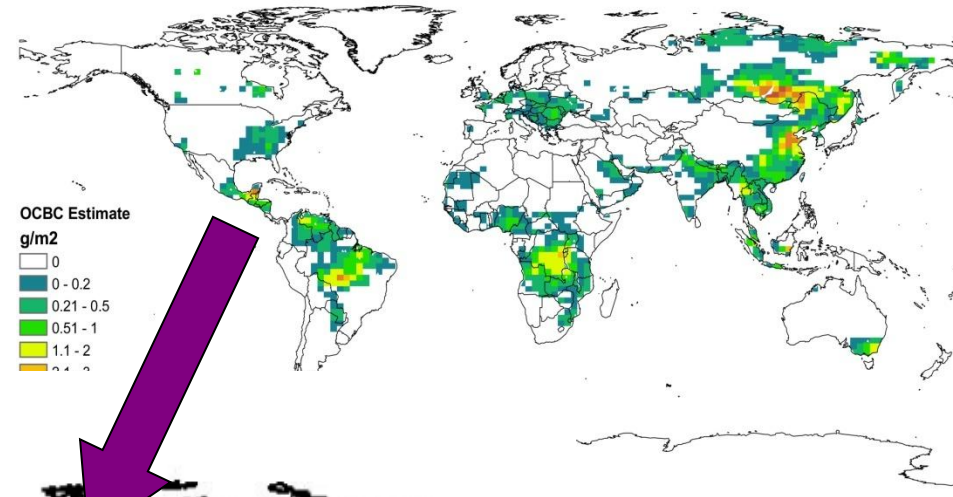
Organic and Black Carbon Aerosols

FRE CMG

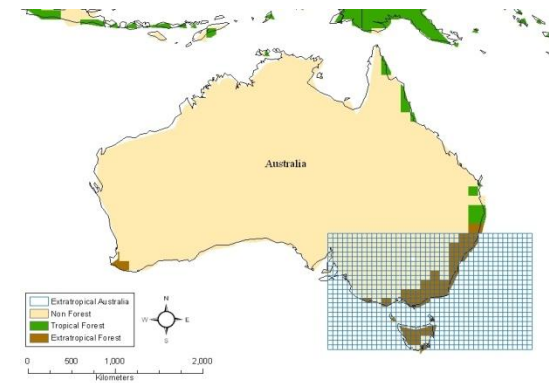
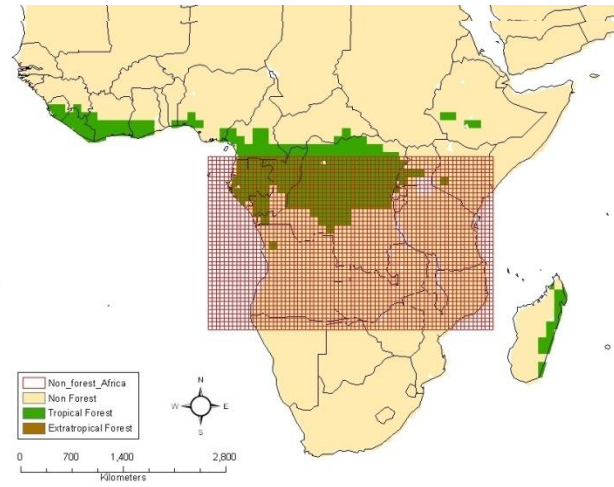
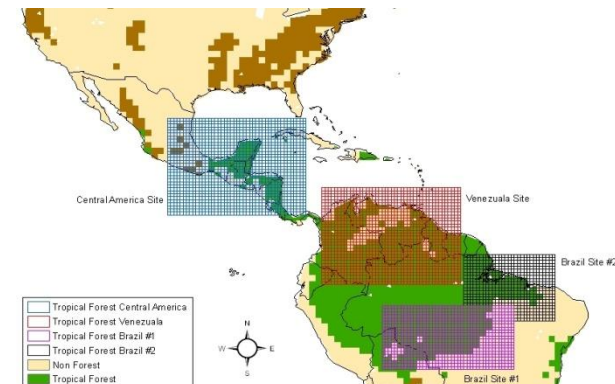
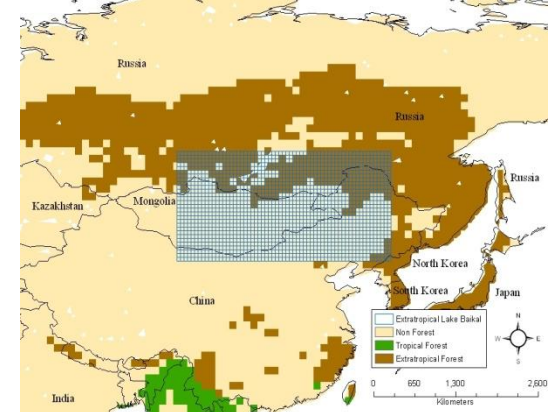
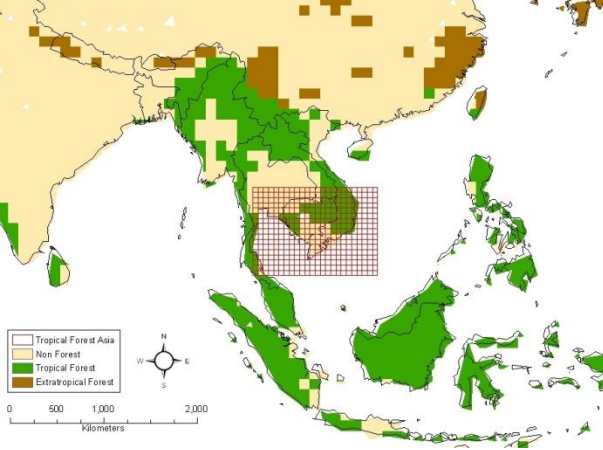
Estimated Total FRE: 2003



OC & BC



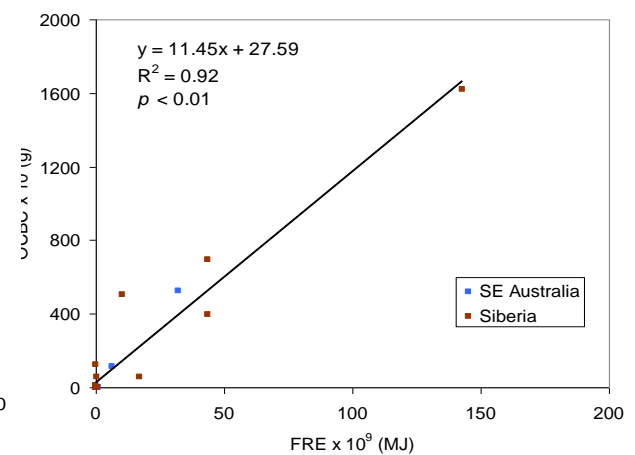
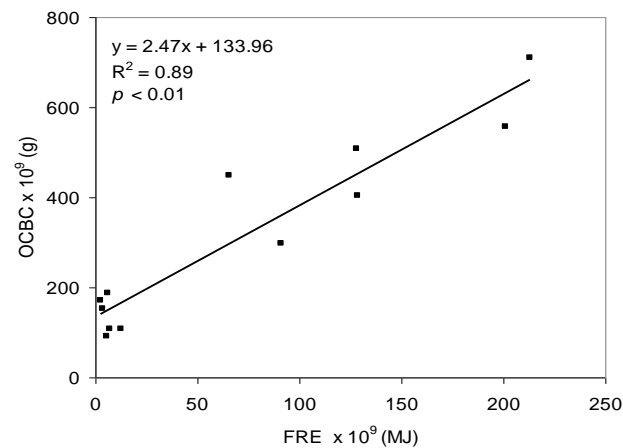
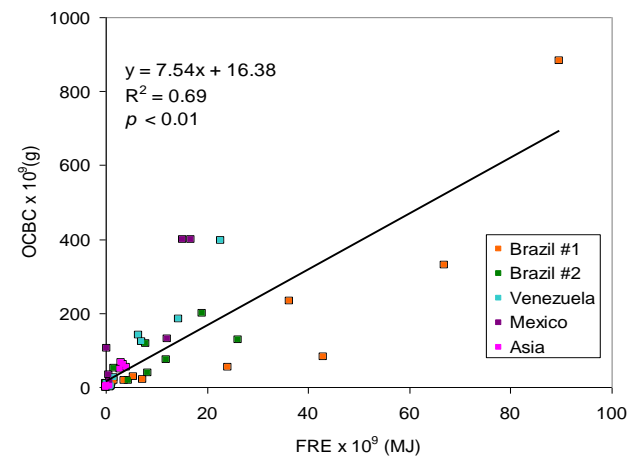
FRE-based emission factors (coefficients)



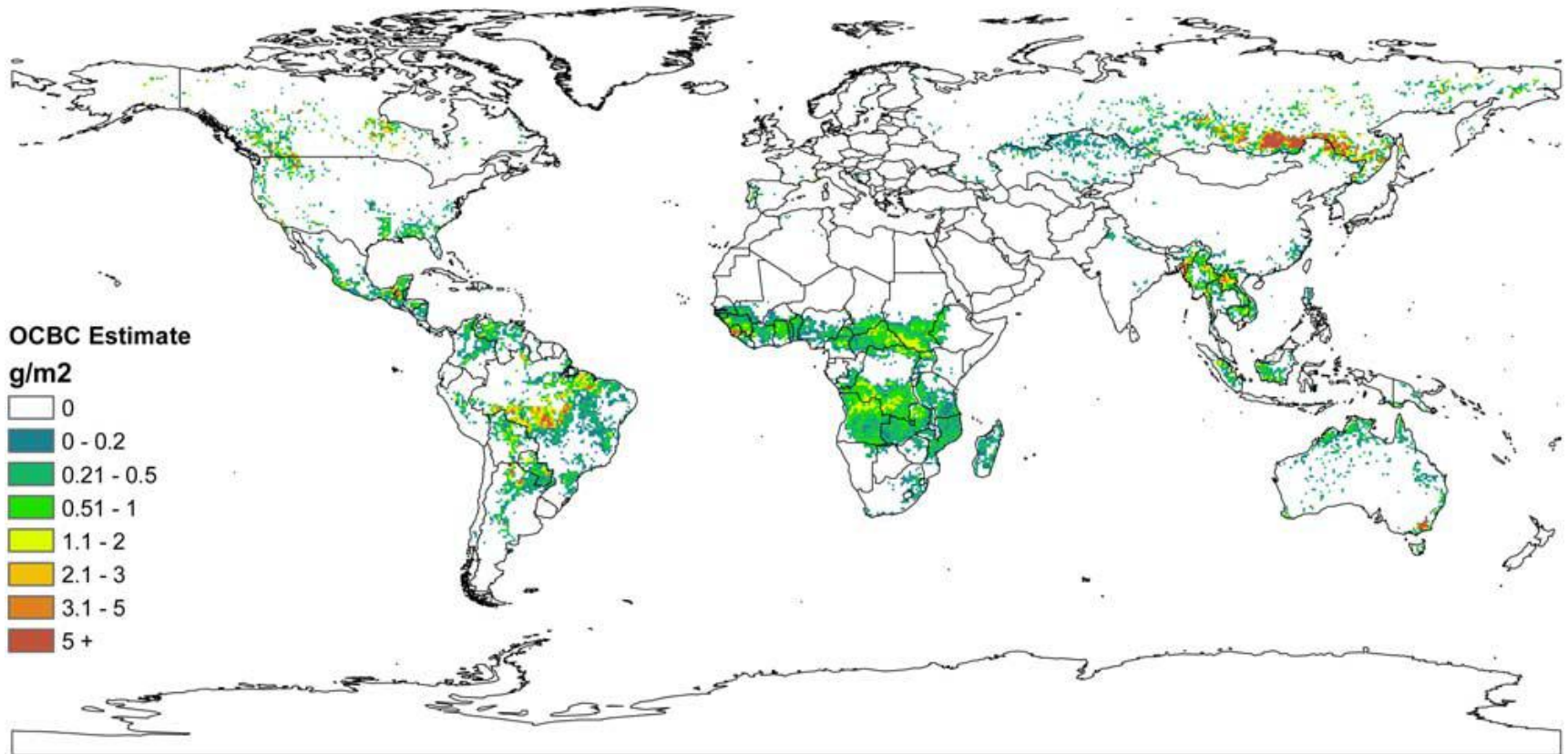
Tropical Forest

Non Forest

Extratropical Forest

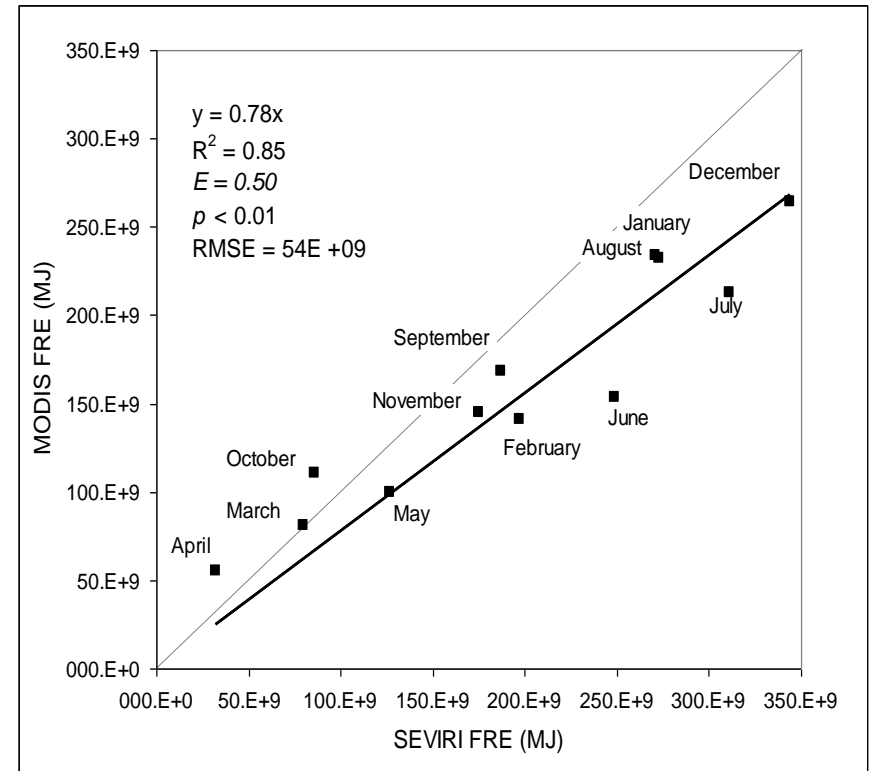


FRE-based Estimated OCBC : 2003



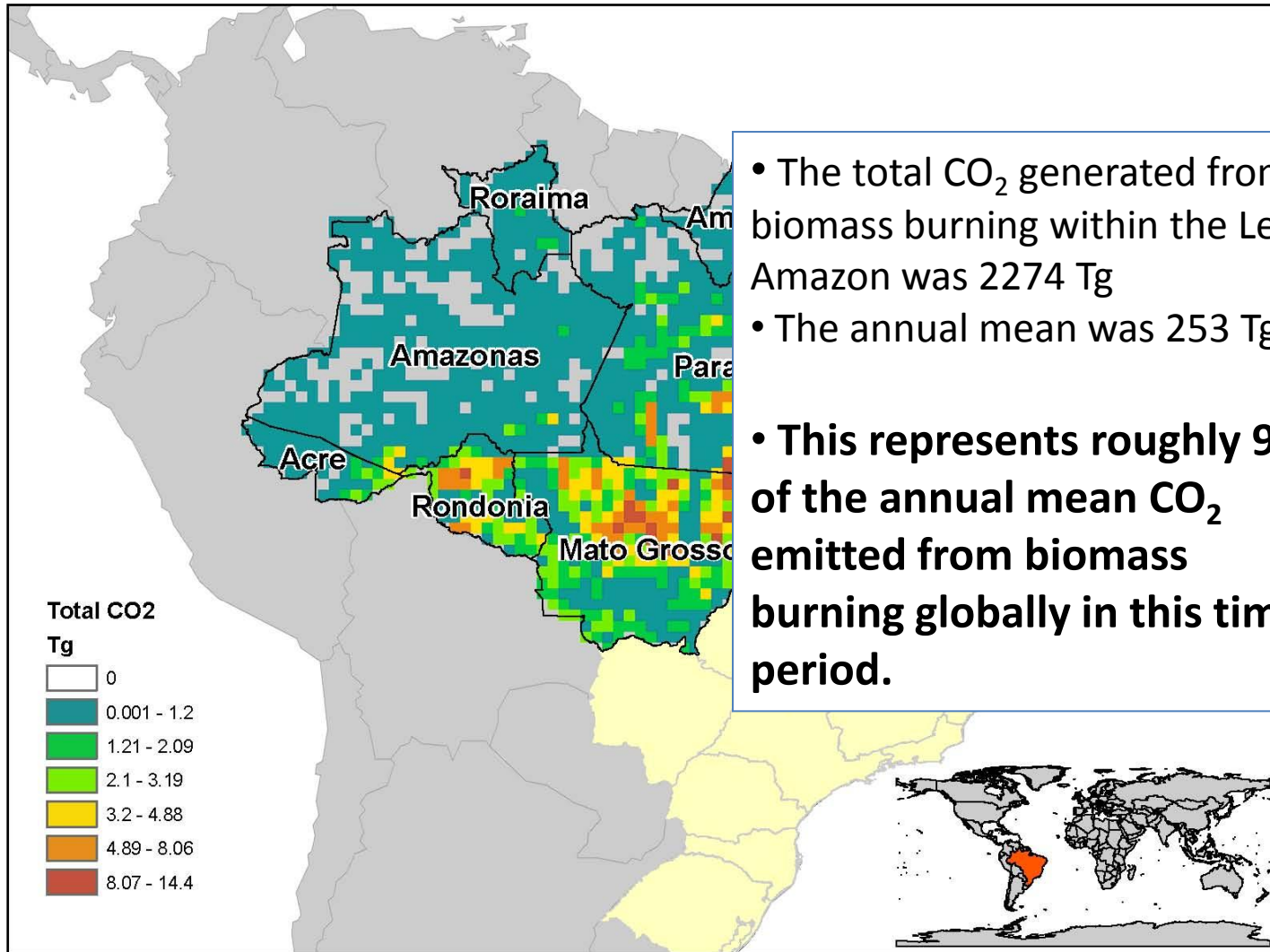
Vermote, E., E. Ellicott, O. Dubovik, T. Lapyonok, M. Chin, L. Giglio, and G. J. Roberts (2009), An approach to estimate global biomass burning emissions of organic and black carbon from MODIS fire radiative power, *J. Geophys. Res.*, 114, D18205, doi:10.1029/2008JD011188.

Applying FRE-based combustion factors to Africa yields an annual average biomass burned of 716–881 Tg of dry matter (DM). Comparison with the GFEDv2 biomass burned estimates shows large annual differences suggesting significant uncertainty remains in emission Estimates.



Ellicott, E., E. Vermote, L. Giglio, and G. Roberts (2009), Estimating biomass consumed from fire using MODIS FRE, Geophys. Res. Lett., 36, L13401, doi:10.1029/2009GL038581.

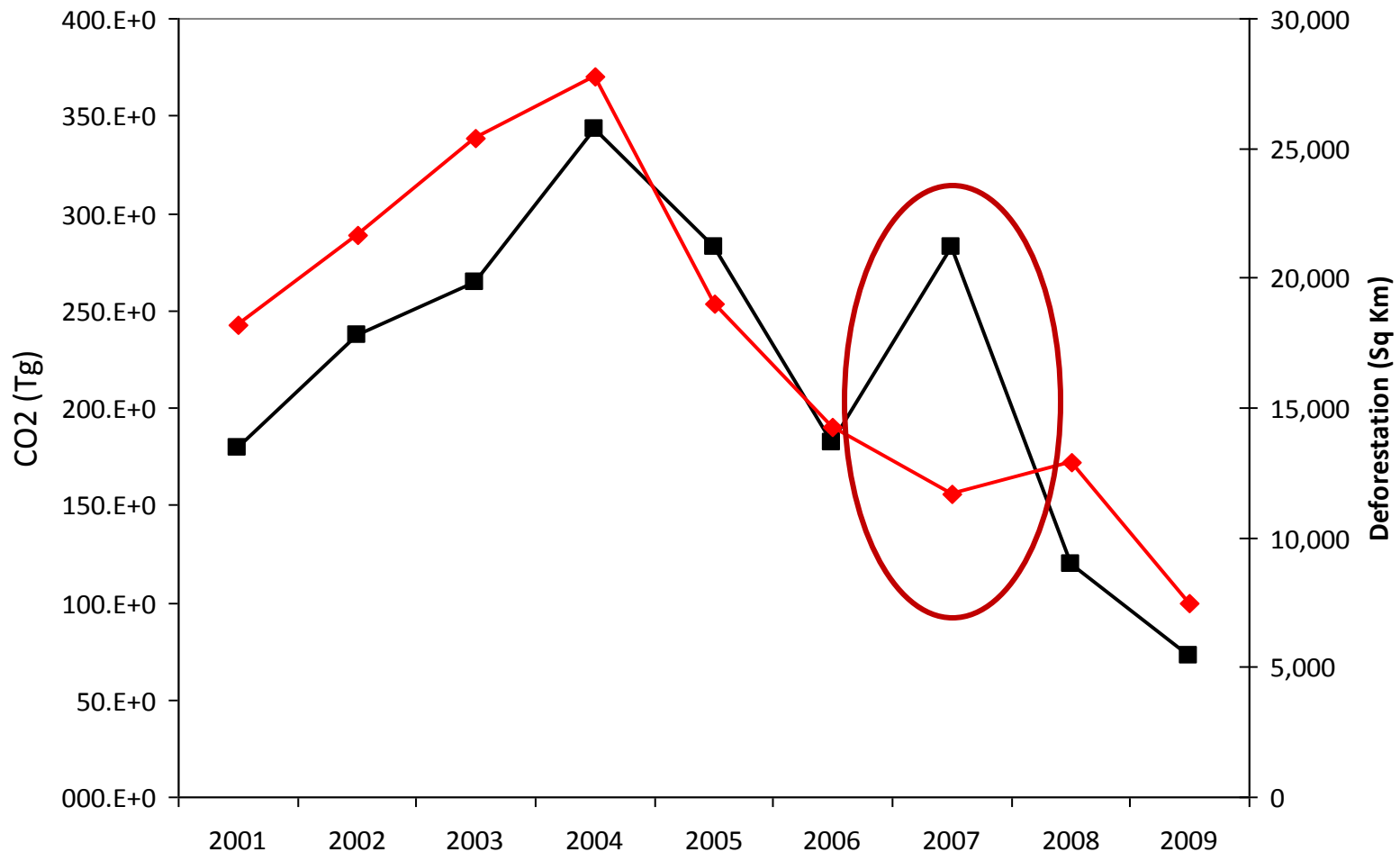
Total CO₂: 2001-2009



- The total CO₂ generated from biomass burning within the Legal Amazon was 2274 Tg
- The annual mean was 253 Tg.
- **This represents roughly 9% of the annual mean CO₂ emitted from biomass burning globally in this time period.**

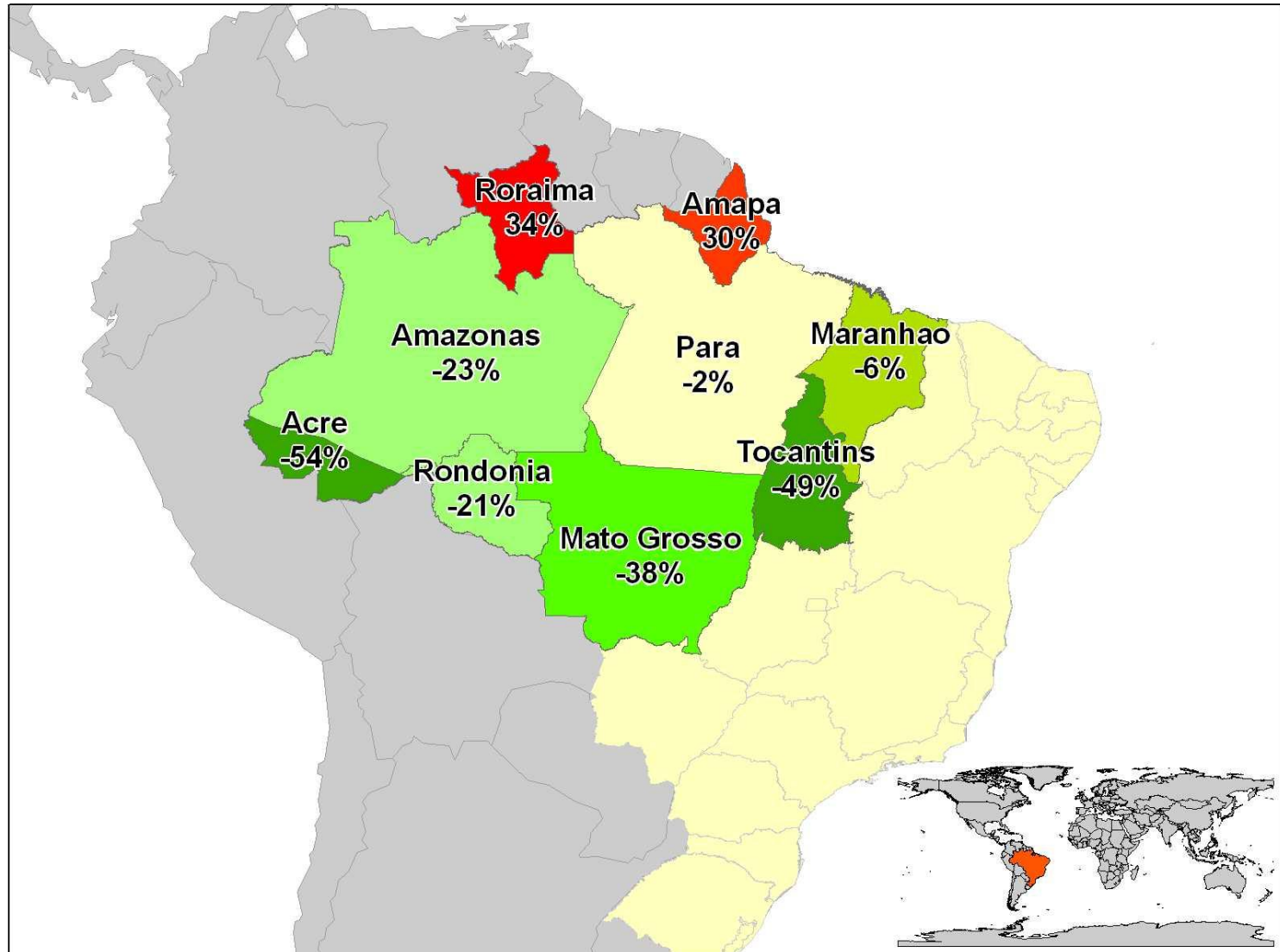
CO₂ and Deforestation

CO₂ emission and Deforestation in the Legal Amazon: 2001-2009

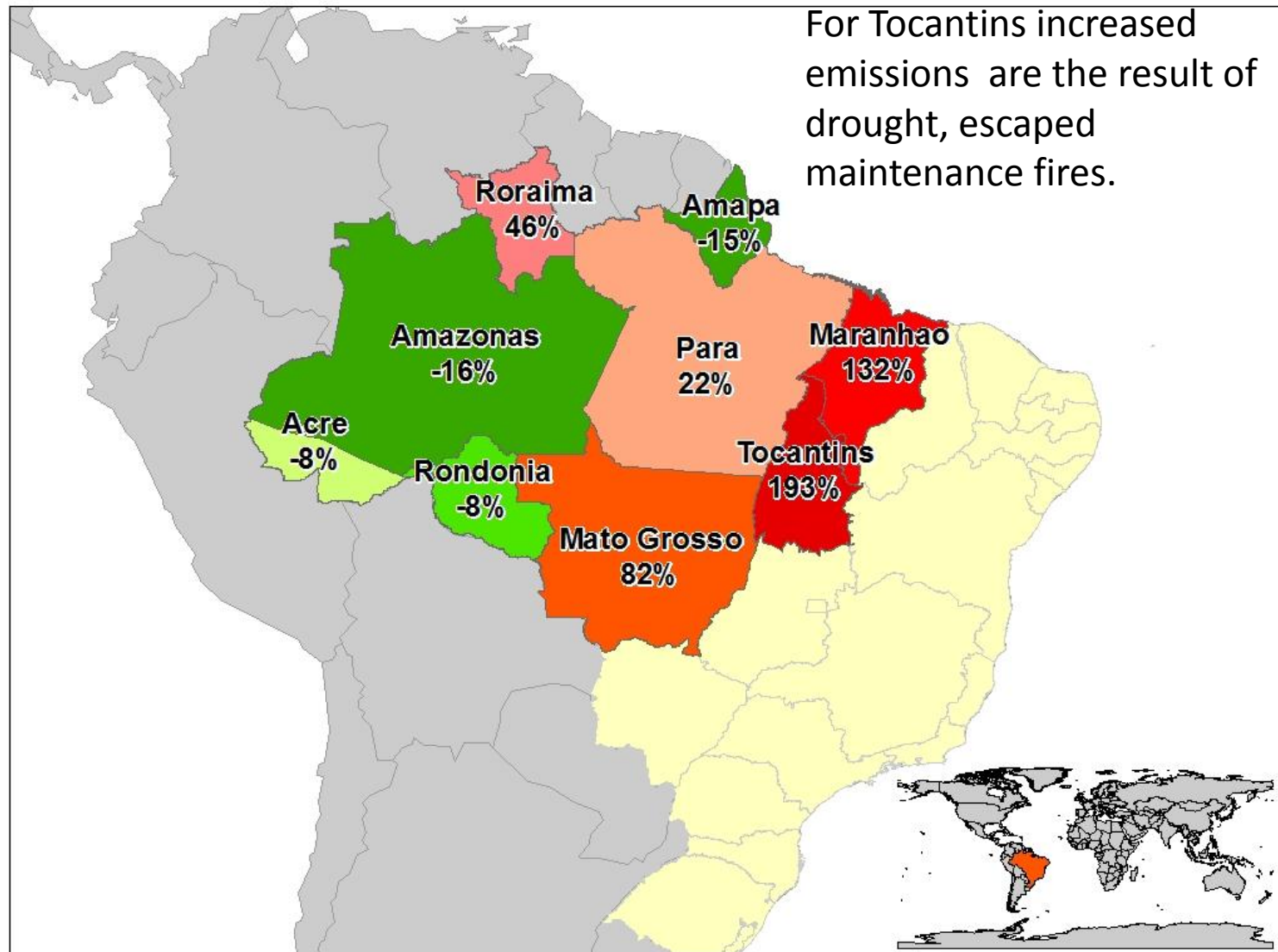


Deforestation change:

2006 → 2007



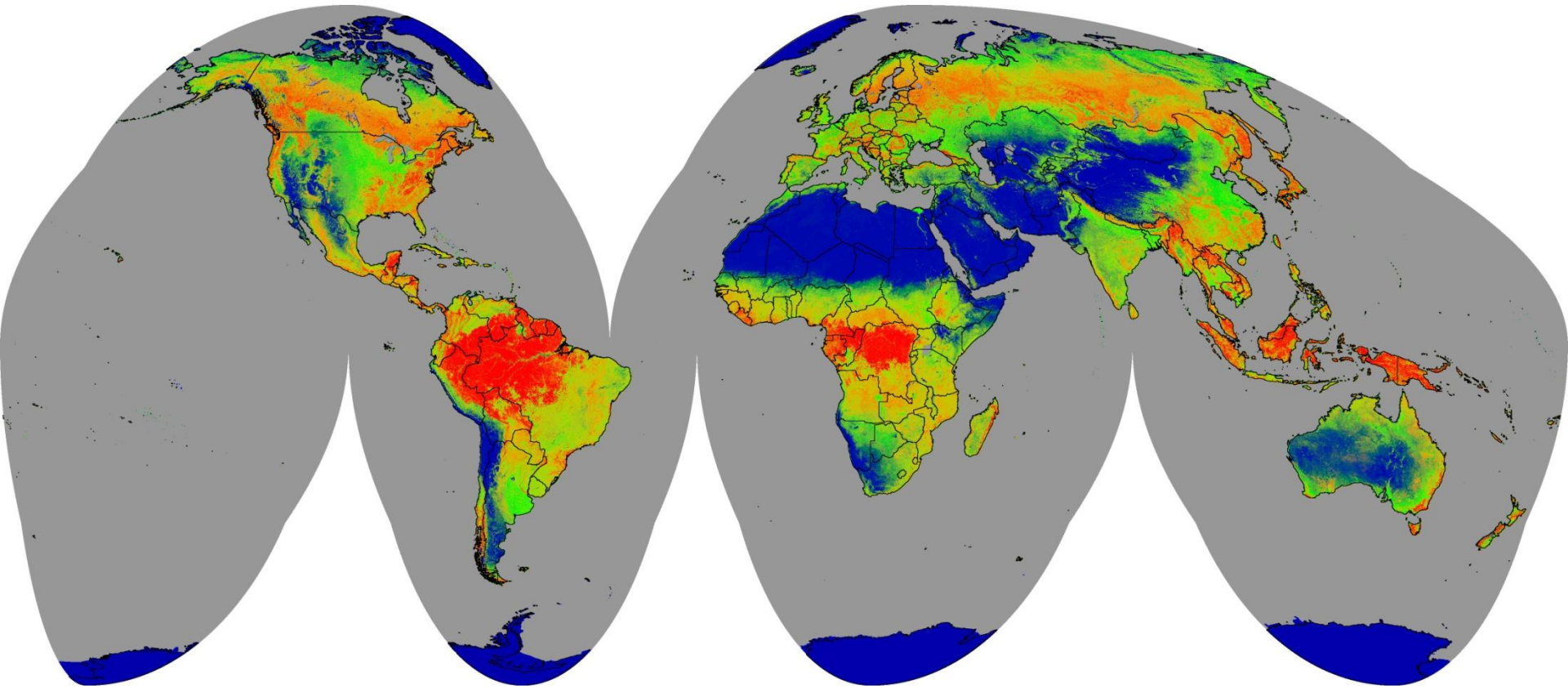
CO₂ change: 2006 → 2007



Transition to Forest Monitoring

- Forest monitoring important not only for conservation and biodiversity studies but also for Carbon Monitoring Reporting and Verification

MODIS Vegetation Continuous Fields – 2000



Bare ground



Grass/shrubs/moss



Trees

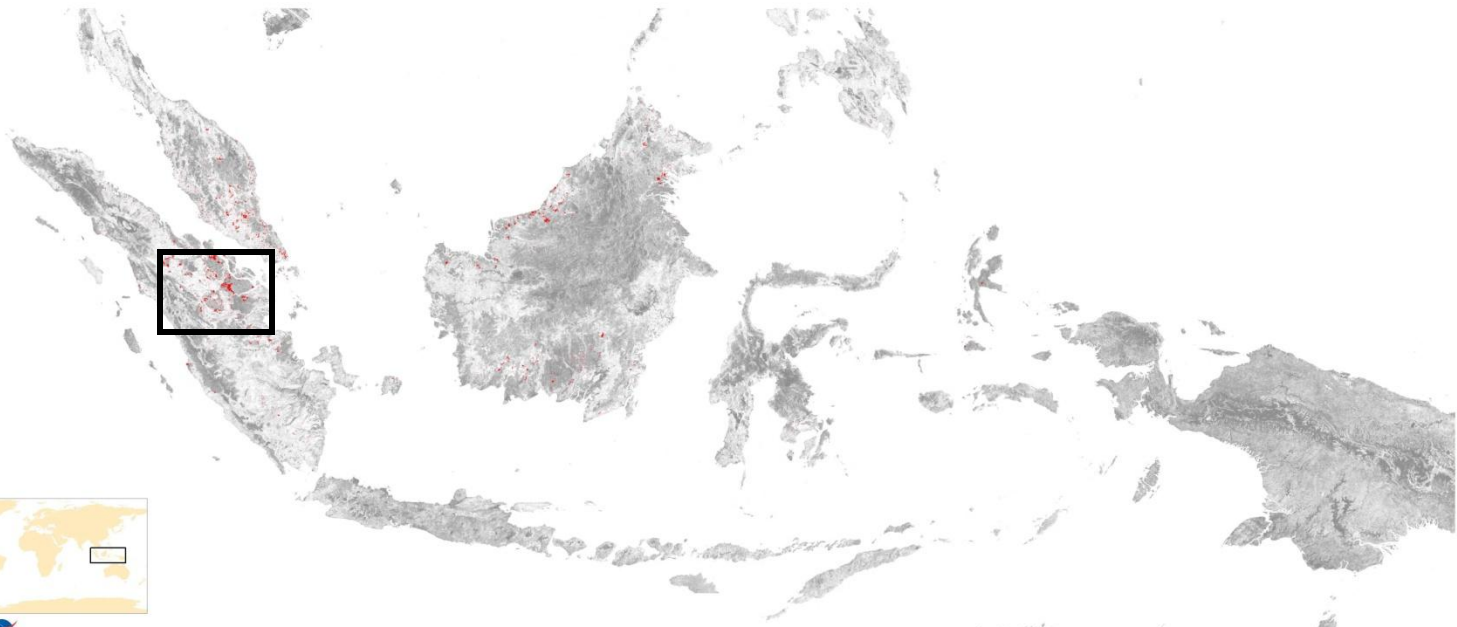
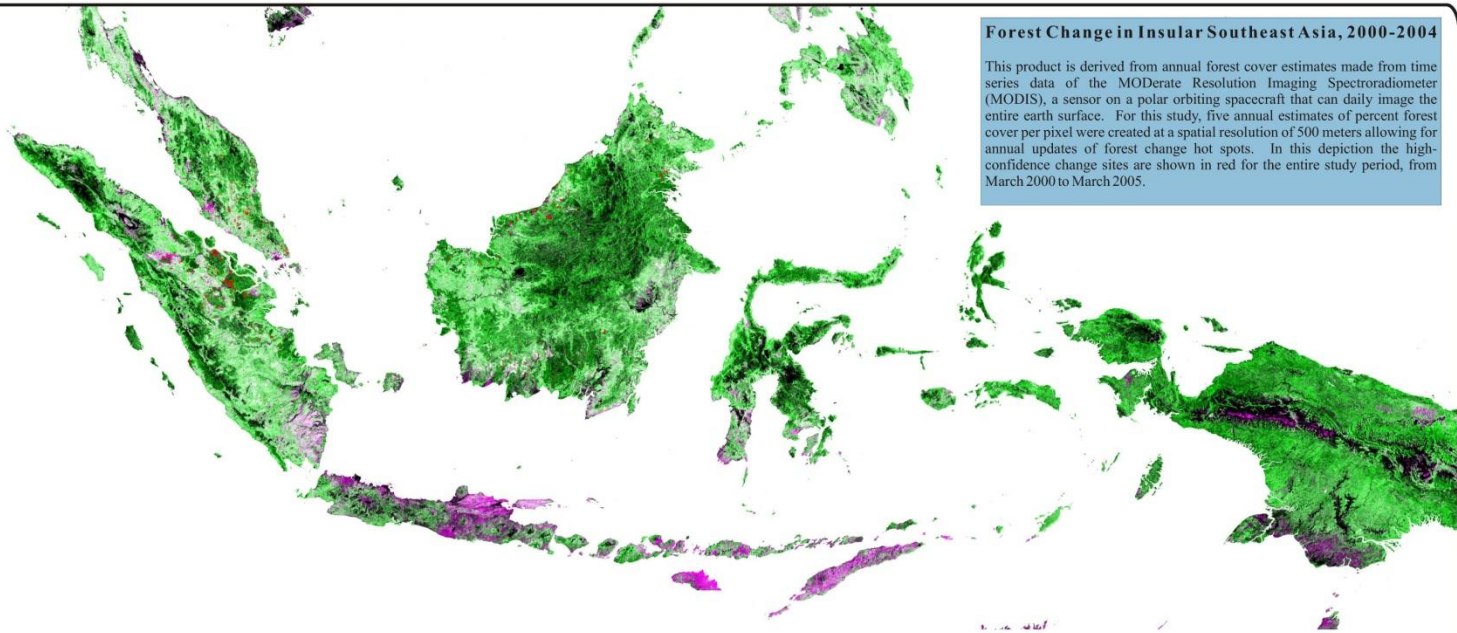


Percent cover 0%

100%

Forest Change in Insular Southeast Asia, 2000-2004

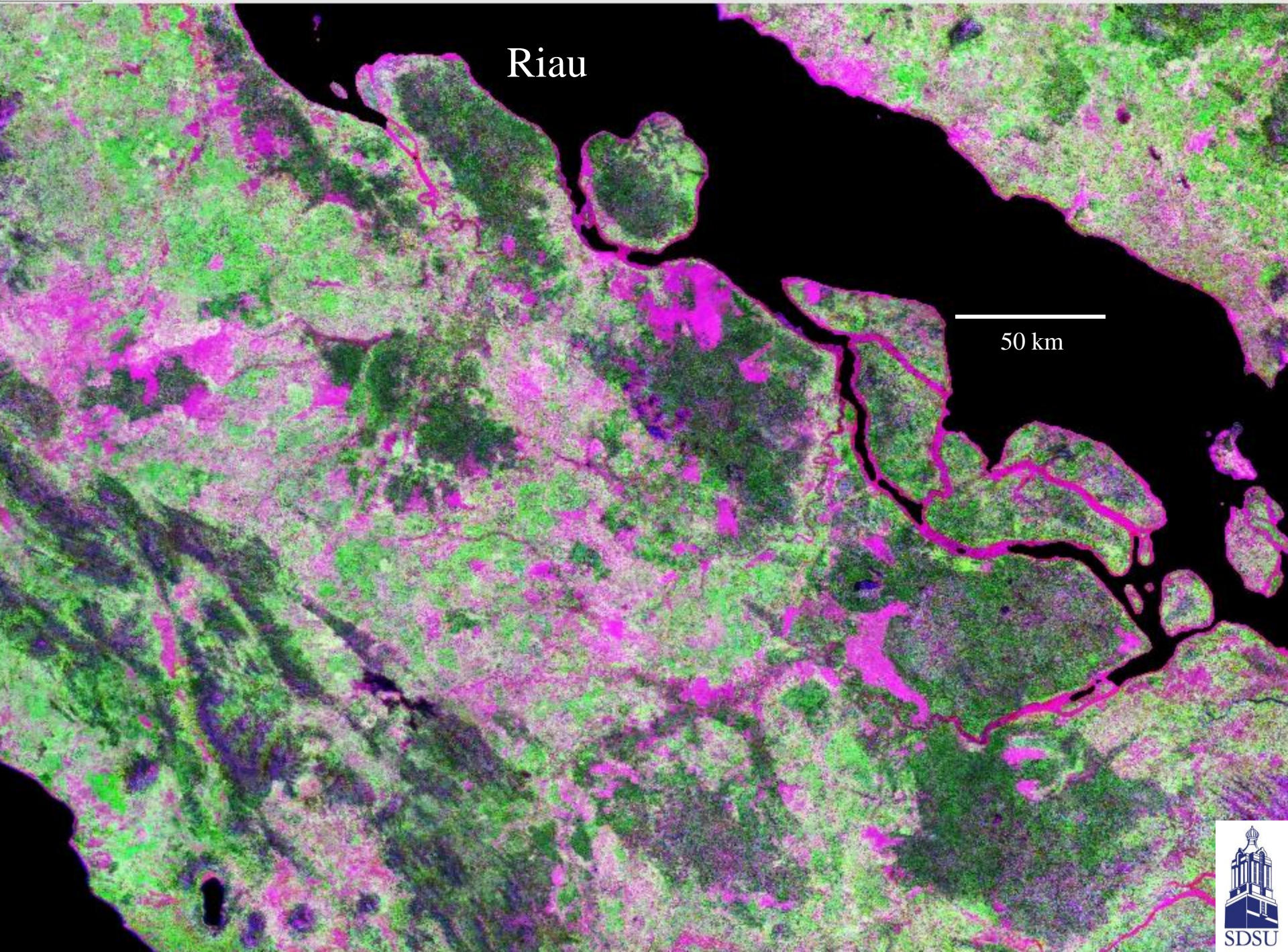
This product is derived from annual forest cover estimates made from time series data of the MODerate Resolution Imaging Spectroradiometer (MODIS), a sensor on a polar orbiting spacecraft that can daily image the entire earth surface. For this study, five annual estimates of percent forest cover per pixel were created at a spatial resolution of 500 meters allowing for annual updates of forest change hot spots. In this depiction the high-confidence change sites are shown in red for the entire study period, from March 2000 to March 2005.



Vicinity Map

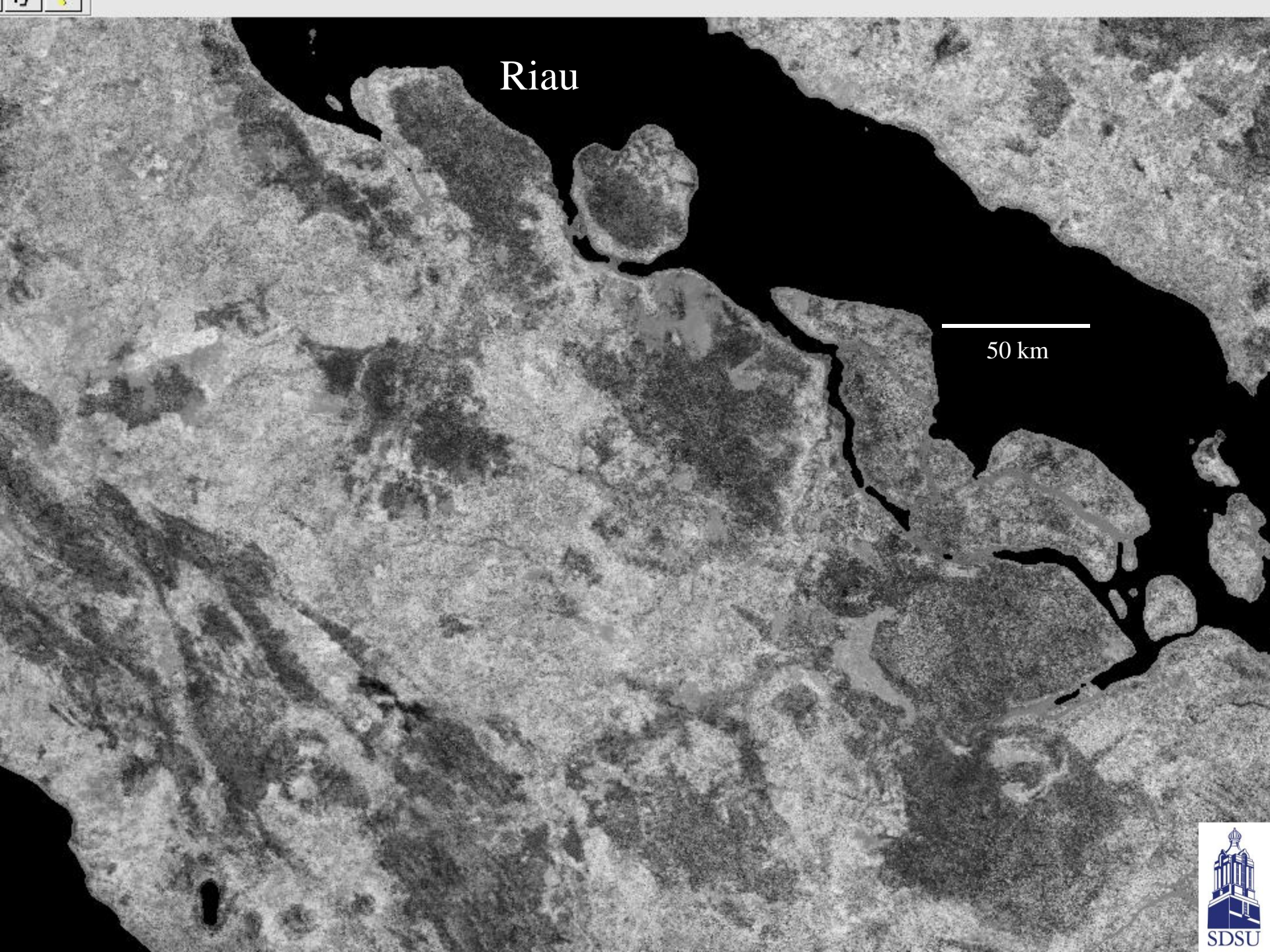


Forest Change in Insular Southeast Asia



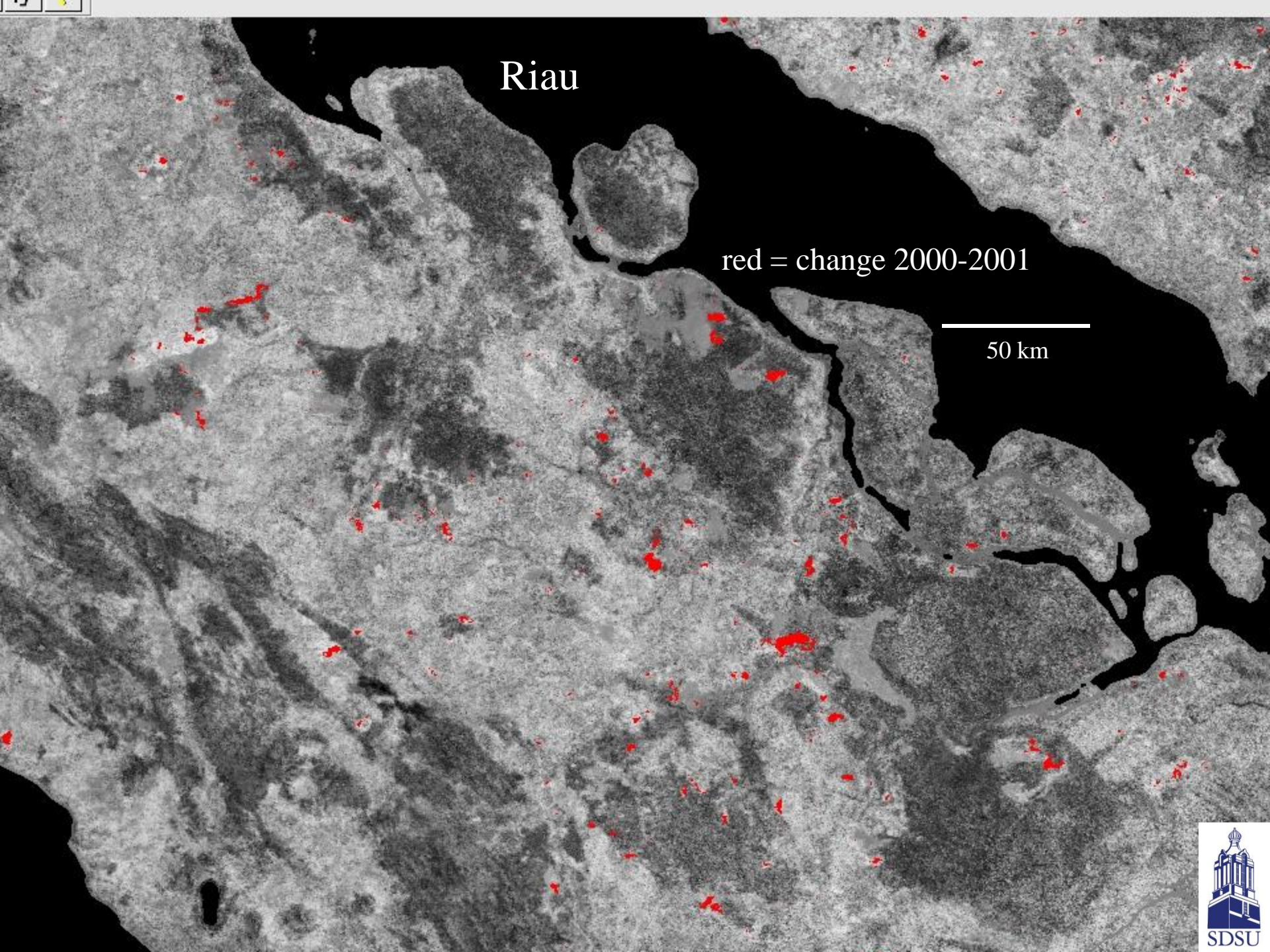
Riau

50 km



Riau

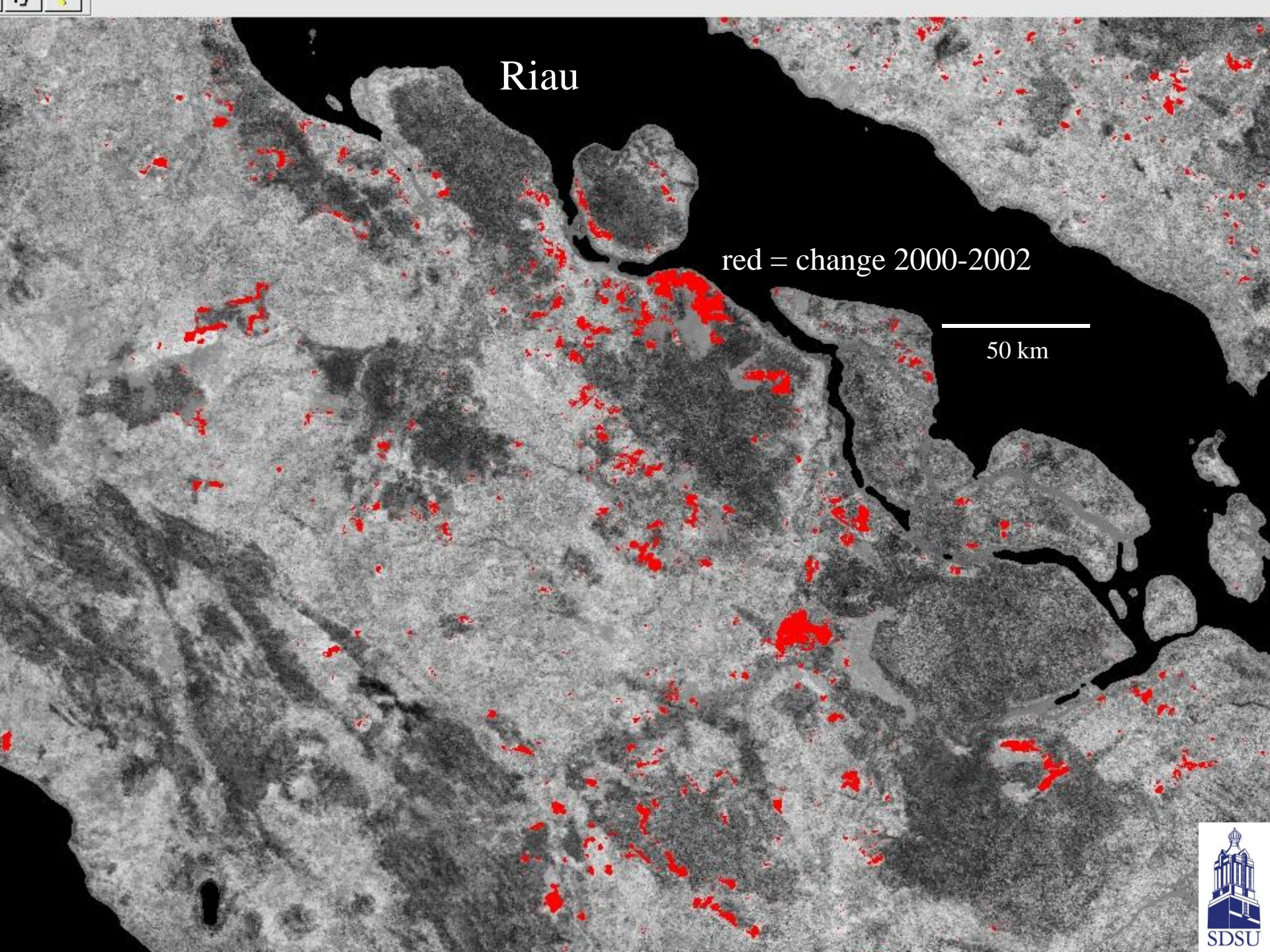
50 km

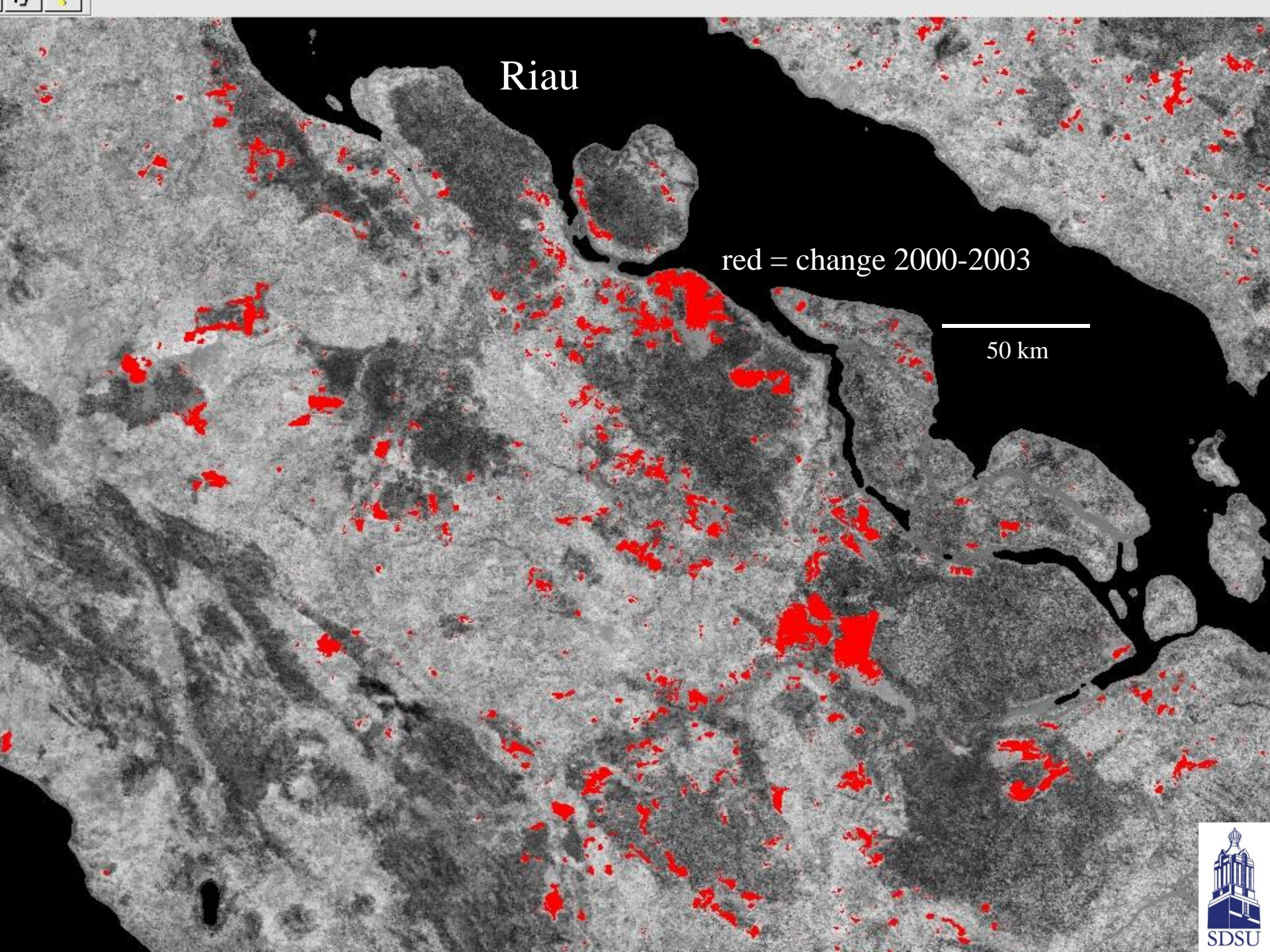


Riau

red = change 2000-2001

50 km

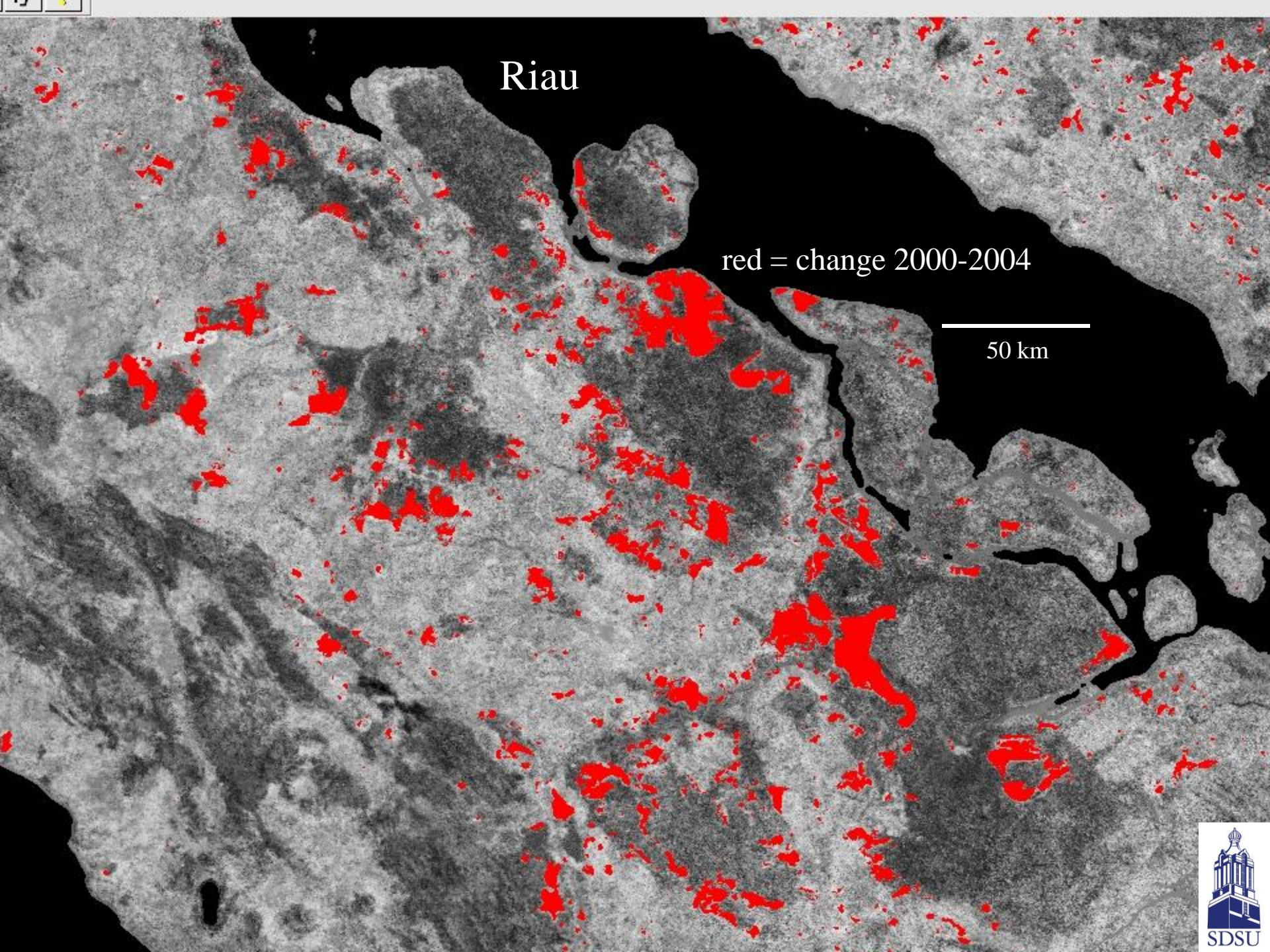




Riau

red = change 2000-2003

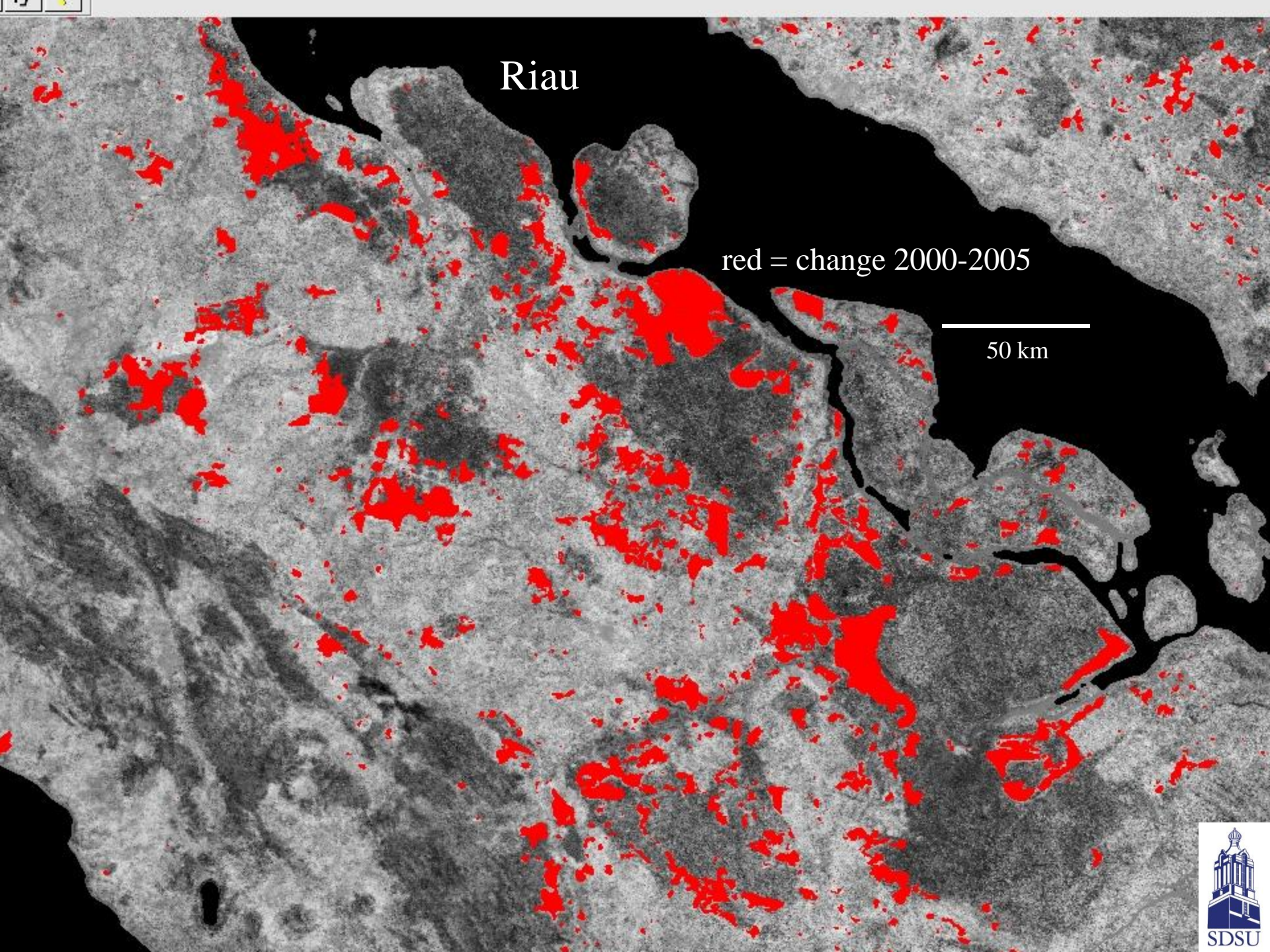
50 km



Riau

red = change 2000-2004

50 km



Riau

red = change 2000-2005

50 km

Operational Deforestation Detection in Brazilian Legal Amazon with MODIS

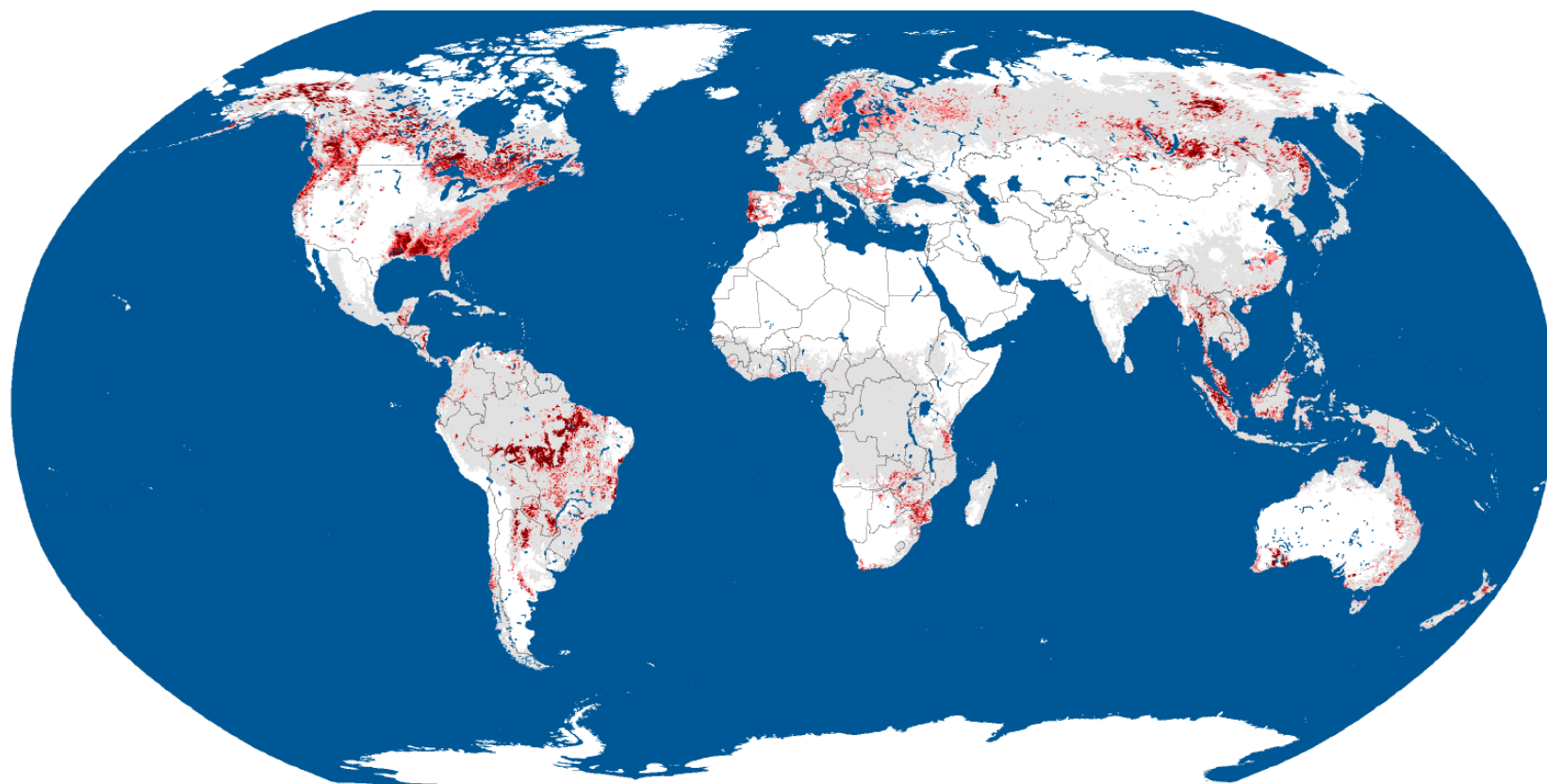
(**DETER** - **DE**tecção em **TE**mpo **R**eal do Desmatamento na Amazônia Legal)

www.obt.inpe.br/deter

- Reference: deforestation map available from the Landsat derived deforestation product (PRODES) for the previous year
- Monthly detection of changes in forested areas without cloud cover
- Rapid production and dissemination of the results using the internet
- Daily acquisitions and free availability key for operational real-time monitoring
- Not a substitute for higher resolution, Landsat-like observations but allows rapid assessment

MODIS used for Global Change Detection

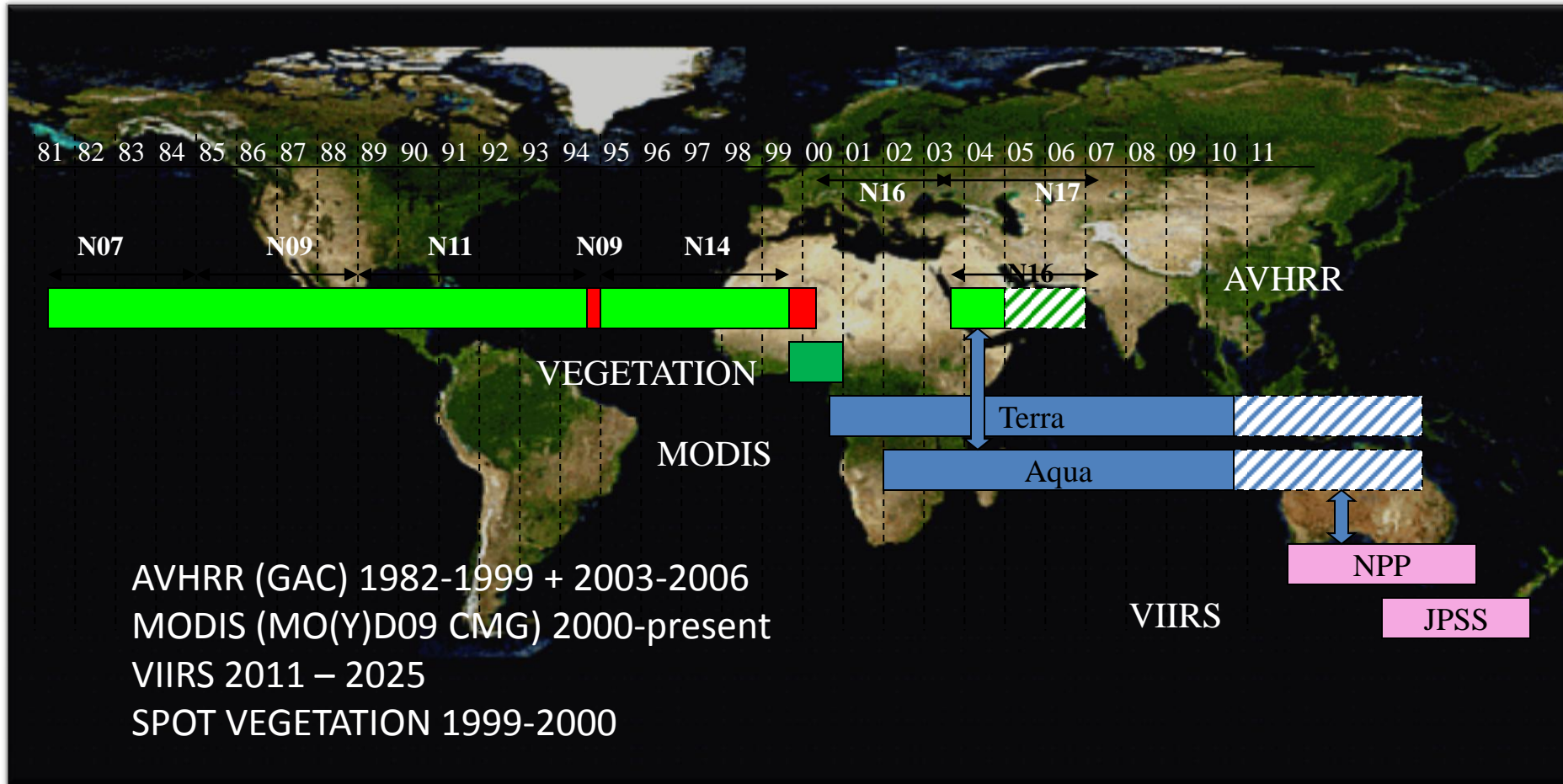
Percent forest cover loss, 2000 to 2005



0 - 1.5% 1.5 - 5% 5 - 10% >10%

Land Climate Data Record

Multi instrument/Multi sensor Science Quality Data Records used to quantify trends and changes



*Emphasis on data consistency – characterization
rather than degrading/smoothing the data*

Eric Vermote et al.

Summary Slide

- **MODIS science products are contributing significantly to Land Applications around the world**
- **International issues are increasingly of National Importance – food security, disaster monitoring, forest carbon monitoring**
- **Tremendous uptake of MODIS and enhancement by the international community – we can benefit from their expertise and involvement**
- **NASA Science Applications program is working with US partner agencies to facilitate research to operational transition**
- **Real opportunities for NASA to contribute to GEOSS**
- **NASA is ensuring science continuity through the NPP VIIRS and subsequent JPSS Mission**
- **Continuity of science quality land products is needed both for research and operations**